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STUDIES ON SKIPJACK IN THE PACIFIC

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STUDIES ON SKIPJACK IN THE PACIFIC

Recent Development in Fisheries for
Skipjack Tuna, Katsuwonus pelamis, in the Central and
Western Pacific and the Indian Ocean

The Stock Structure of Skipjack Resources
and the Possible Implications on the Development of
Skipjack Fisheries in the Central and Western Pacific

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 1975

PREPARATION OF THIS DOCUMENT

This document summarises the present state of knowledge of the stocks of skipjack tuna, Katsuwonus pelamis, in the Central and Western Pacific and the Indian Ocean, and their potentials. It constitutes a contribution to FAO World Appraisal of Fishery Resources Programme.

The World Appraisal of Fishery Resources is a continuing programme of FAO, maintained by the Fishery Resources and Environment Division in close cooperation with national and regional fishery bodies and experts for a comprehensive and up-dated review and dissemination of information on the state of the world's marine and inland living resources and their potentials. Major outputs of this programme have so far been the review on "The Fish Resources of the Ocean" (FAO Fisheries Technical Paper No. 97) which has been published under the same title as a book by Fishing News (Books) Ltd., and the "Atlas of the Living Resources of the Seas" published by FAO in 1972.

With the participation of the United Nations Environment Programme (UNEP), this activity is being progressively developed to provide a regular service to member governments and other utilizers. The present review is prepared as part of the FAO/UNEP Project on Monitoring of Environmental Effects on Marine World Fishery Resources, which will provide the required review of knowledge on the size and the state of world marine fish resources.

The first paper was prepared by Mr. R.N. Uchida of the U.S. National Marine Fisheries Service, Southwest Fisheries Center, Honolulu, as a working document for the Second Session of the IPFC/IOFC ad hoc Working Party of Scientists on Stock Assessment of Tuna, which met in Nantes in September 1974. The other paper was prepared by Dr. R.E. Kearney while he was employed by FAO as a Consultant at FAO Headquarters in Rome. The views expressed in these papers are those of the authors and not necessarily those of FAO.

Distribution

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Bibliographic entries

Uchida, R.N. (1975)
FAO Fish.Tech.Pap., (144):1-57
Studies on skipjack in the Pacific.
Recent development in fisheries for skipjack tuna, Katsuwonus pelamis, in the Central and Western Pacific and the Indian Ocean

Tuna; Fishery development; Catch statistics; Landing statistics; Exploratory fishing. Central Pacific; Western Pacific; Indian Ocean.

Kearney, R.E. (1975)
FAO Fish.Tech.Pap., (144):59-69
Studies on skipjack in the Pacific.
The stock structure of skipjack resources and the possible implications on the development of skipjack fisheries in the Central and Western Pacific

Species composition; Serological studies; Size distribution; Horizontal migrations; Growth; Spawning; Baitfish resources. Central Pacific; Western Pacific; Indian Ocean.

FOREWORD

In all oceanic areas large tuna species (albacore, bigeye, blackfin, northern and southern bluefin and yellowfin tunas) appear to be now nearly fully exploited. Increased effort will result at best in small, if any, increase in catches and may well for some stocks lead to some decrease in annual yield. On the other hand, skipjack (Katsuwonus pelamis) resources are believed to offer better perspectives: their stocks are generally abundant and, in most areas, probably only moderately fished; new fisheries are developing, particularly in the Western Central Pacific.

In spite of these better long-term perspectives, development of skipjack fisheries is in various areas encountering noticeable difficulties: the catchability of the species is often reduced by its distribution in scattered, small and highly mobile schools; limited bait availability frequently thwarts the development of pole-and-line fishing, whereas in areas with clear waters and deep thermocline purse seining performances are often disappointing.

Despite these difficulties catches of skipjack are increasing, though probably slower than the long-term trends in demand. A growing number of developing countries are participating, or planning to participate, in skipjack fishery, partly through joint ventures with developed countries, but this participation is hindered by lack of information. Dissemination of up-to-date information on skipjack resources and on recent developments relevant to their fisheries is therefore essential. In this publication two studies on the skipjack resources and fisheries in the Pacific and Indian Oceans are presented. Particular emphasis is laid on areas where attempts to introduce skipjack fishing has recently been most successful.

In the Pacific Ocean, skipjack fishing has a long history, particularly the Japanese fisheries in the Northwest Pacific and the U.S. operations in the Eastern Central Pacific. More recent is the rapid expansion of Japanese activities on fishing grounds south of those traditionally exploited, as well as the thriving development of joint ventures - involving mostly Japanese and local interests - which is taking place in the Pacific southwestern equatorial region. As a result the total skipjack production of the Western Pacific (FAO statistical areas 61 and 71) has increased from 200 thousand tons in 1967 to 320 thousand tons in 1973. The latter represents 70% of the world catch of this species, and the skipjack contribution as a percentage of the total tuna catches, is about twice as high in the Western Pacific as in the world as a whole (Table 1).

In the Indian Ocean, skipjack fisheries are still - with the exception of restricted local areas - little developed. Present catches make up only 4% of the world catch (Table 1). However, traditional fisheries, recent exploratory surveys and initial commercial fishing operations have revealed that the perspectives are definitely good in several zones such as around the islands southwest of the Indian subcontinent (Laccadive-Maldive Islands) or within the triangle Seychelles Islands - Comores Islands - northwestern coast of Madagascar.

The first document "Recent developments in fisheries for skipjack tuna, Katsuwonus pelamis, in the Central and Western Pacific and the Indian Ocean" presented here has been prepared by R.N. Uchida, Southwest Fisheries Center, Honolulu, Hawaii, for the second session of the IPFC/IOFC Ad hoc Working Party of Scientists on Stock Assessment of Tuna, held in Nantes, France, from 16 to 18 September 1974. It contains an extensive review - presented country by country - of the recent developments in the skipjack fisheries in the Pacific and Indian Oceans. The information on skipjack resources derived from traditional - including artisanal - fishing activities, exploratory survey findings and performances of newly established commercial operations is supplemented by data on bait resources (species, location, catch rates, etc.) for, as already mentioned, the successful development of skipjack fisheries depends, in many areas, on the availability of such resources.

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RECENT DEVELOPMENT IN FISHERIES FOR SKIPJACK TUNA, *Katsuwonus pelamis*, IN THE CENTRAL AND WESTERN PACIFIC AND THE INDIAN OCEAN

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1. INTRODUCTION

At the World Scientific Meeting on the Biology of Tunas and Related Species held at La Jolla, California in July 1962, Chapman (1963) stated: "In the United States the market for canned tuna has a little more than doubled every ten years for the past fifty years and is still increasing at about the same rate." The world tuna production reached roughly 400 000 tons in 1950 and close to 800 000 tons by 1960. By 1970, Chapman estimated the world tuna market would require about 1 500 000 tons of tuna. Chapman's estimate was remarkably close. In 1970, according to FAO statistics (FAO, 1972), the world's production of tuna and tuna-like fishes reached 1 427 000 tons.

Roughly half of the 1970 production consisted of yellowfin tuna (Thunnus albacares), and skipjack tuna (Katsuwonus pelamis), but yellowfin tuna production appears to be stabilizing and a substantial increase in catches of this species seems unlikely. Intensive investigations by the Inter-American Tropical Tuna Commission (IATTC) demonstrated that there was a need to implement conservation measures for yellowfin tuna in the east Pacific fishery. This led to regulation of the yellowfin tuna stocks in the east Pacific (Joseph, 1970). Kamimura (1966) has also shown that increases in effort for yellowfin tuna in the longline fishery beyond the 1962 level would not increase the catch.

Concerning skipjack tuna, the apparent abundance has not been affected despite the large catches (Broadhead and Barrett, 1964; Kawasaki, 1965; Rothschild and Uchida, 1968). In 1960-73, the east Pacific fishery produced catches that ranged between 31 933 and 122 381 metric tons (t) and averaged 68 691 t (Table 1). In the west Pacific, Japanese catches in the coastal and southern water fisheries have varied from 78 608 to 201 000 t and averaged 145 110 t. The frequently made observations that there are no observable effects of fishing on the established fisheries in Japan or the coasts of the Americas and that there is sizable potential skipjack tuna yield, have induced the tuna-producing nations to turn to this species for increased production.

Essentially, the major effort in the tremendous expansion of skipjack tuna fishing has come from Japan. Realizing that no large increase in yield can be expected from the large tunas, the Japan Fisheries Agency announced a policy of skipjack tuna development on a large scale. In the opinion of some Japanese scientists, effort should not be expended to further develop the Japanese coastal skipjack tuna fishery or the present southern water fishery operating in the Bonin, Mariana, Caroline, and Marshall Islands (Kasahara, 1971; Kawasaki, 1972). The expansion, they feel, should concentrate on developing new fishing grounds in distant waters. As early as 1967, the Japanese were actively pursuing the formation of cooperative surveys with foreign governments (Katsuo-Maguro Nenkan, 1973). For example, with the signing of the Japan-Australia Fishing Treaty in 1968, the Japanese began fishery surveys which eventually led to formation of joint ventures in Papua New Guinea.

This report reviews areas of the central and west Pacific and the Indian Ocean where fisheries for skipjack tuna have developed in recent years or where the potential for skipjack tuna fishery expansion or development lies. Geographically, the coverage is fairly extensive with major emphasis on the Pacific islands ranging across the tropical Pacific from Indonesia to the Marquesas Islands. The Japanese coastal and southern water fisheries and the east Pacific fishery within the scope of IATTC, both well documented in the literature, have been omitted.

2. CENTRAL PACIFIC OCEAN

The present theory of stock separation and migration is that the skipjack tuna population in the Pacific is composed of a west Pacific stock that ranges from the Philippine Sea to Japan and from the Ryukyus south to New Guinea and into the Coral Sea, and a central Pacific stock that probably extends from the Carolines and the eastern portion of the Marianas to the Americas (Fujino, 1967, 1970, 1972). More detailed information on the stock composition in the west and central Pacific is given in the second part of the present document prepared by Kearney.

For convenience, the Pacific islands and nations dealt with in this review have been divided into two groups. Those lying between 130°W and 180°W were classified under central Pacific; those from 180°W to the islands bordering the Indian Ocean were considered in the west Pacific. The groups in the central Pacific include the island groups of French Polynesia, the Hawaiian Islands, Samoa Islands, and Tonga Islands (Figure 1).

2.1 French Polynesia

The island groups in French Polynesia include the Society, Tuamotu, Gambier, Rapa, Austral, and Marquesas Islands. Tahiti, in the Windward Islands of the Society group, is the only island in French Polynesia with a small commercial fisnery for skipjack and yellowfin tunas. The fishery was described in detail by Van Campen (1953) and Van Pel and Devambez (1957).

Briefly, Tahitian fishermen use small, fast boats called "bonitier" (Brun and Klawe, 1968). These diesel-powered craft, measuring about 9 m in length, can accommodate three men. No refrigeration is used; therefore, each boat returns in the afternoon to unload its catch.

The fishermen locate schools of yellowfin and skipjack tunas by scouting for bird flocks. Also, in recent years trolling lines have been used when searching for surface schools (Brun and Klawe, 1968). When a school is encountered, the boat is kept underway and moving with the school. The fishermen, using pole and line to which a pearl-shell lure is attached, slap and drag the lure on the surface of the water until the fish strikes. The hooked fish is flipped into the boat cockpit. In order to return the hook to the water as rapidly as possible, the fishermen shake the lure loose, disengaging the hooked fish while it is in the middle of its trajectory.

The growth of this fishery is reflected in the steady increase in the number of boats employed. Figure 2 shows that only 15 boats were fishing in 1954 but by 1967 there were 107 (Brun and Klawe, 1968). The fleet size has apparently stabilized; in 1972 there were 97 skipjack tuna fishing boats involved in pearl-shell lure fishing (Doumenge, 1973).

Doumenge (1973) reported that not all Tahitian bonitier go out to fish regularly. About half fish full time; others are idled periodically either for want of crew or for maintenance. Some boats operate only part time when the market is glutted and prices are low.

Figure 2 also shows that in 1954–67 the landings of tuna increased with the number of boats engaged in the fishery (Brun and Klawe, 1968). In this period, annual skipjack tuna landings fluctuated between 252 and 731 t and averaged 379 t. Annual landings of yellowfin tuna were smaller and varied from 41 to 126 t, averaging 77 t.

The skipjack and yellowfin tuna landings shown in Tables 2, 3, and 4 actually represent only about a third to a half of the true production of tuna from Tahiti. There are two important sources of error: first, because the fish are gilled and gutted at sea, the landings at Papeete Municipal Market represent weights of eviscerated fish (Brun and Klawe, 1968); and secondly, many fishermen dispose of their catches directly to local fish dealers or through roadside and door-to-door sales (Doumenge, 1973). The result is that only the surplus is sold through the Papeete Municipal Market; thus, the true production is considerably higher than the reported landings.

In 1972–73, to determine the feasibility of catching surface schools of skipjack and yellowfin tunas by pole and line and live bait in French Polynesian waters, the Service de la Pêche, Polynésie Française (Fisheries Department of the Territory of French Polynesia), arranged to have three bait boats carry out fishing trials (U.S. National Marine Fisheries Service (NMFS), 1972g; Doumenge, 1973). These trials, although involving mostly the Windward Islands, were also extended to the Leeward Islands and parts of the Tuamotu and Marquesas Islands.

The results of these trials are summarized in Tables 5 and 6. Initial catches of the fishing boat MOETU in the Windward Islands in February-June 1972 were not encouraging. Catch per trip averaged only 0.3 t in 28 trips. In December 1972-February 1973, however, the Hawaiian pole-and-line boat, ANELA, did very well. Despite difficulty in obtaining enough live bait to fish continuously (Captain George Higashide and crew, c/o Hawaiian Tuna Packers, P.O. Box 238, Honolulu, Hawaii 96809, personal communication), ANELA logged 19 trips and caught an average of 5.4 t per trip. REDONDO, the third boat engaged, fished on five trips in March-April 1973 and produced about 1 ton per trip.

In 20 trips to the Leeward Islands, MOETU caught an average of 0.6 t per trip which was considerably better than the catch rate in the Windward Islands during the same period (Doumenge, 1973). ANELA, in six trips, confirmed the excellent prospects of the Leeward Islands fishing ground by producing an average of 3.0 t per trip.

Fishing in the Tuamotu Islands proved disappointing (Table 5). MOETU produced less than 0.1 t per trip and ANELA caught only 0.2 t per trip. In the Marquesas Islands, however, six fishing trips by ANELA yielded an excellent catch per trip of 4.7 t.

These fishing trials gave ample indication of tuna but not of a sustained abundance of baitfish. ANELA found bait supplies limited and most of the bait used were juveniles of the scad mackerel (Trachurops sp.) and jacks that were caught by night baiting. Many problems need to be solved before a commercial pole-and-line, livebait fishery can be successfully established in French Polynesia.

2.2 Hawaiian Islands

The fishery for skipjack tuna in the Hawaiian Islands has been adequately described in a number of publications (June, 1951; Yamashita, 1958; Uchida, 1966). Briefly, it is a pole-and-line fishery that began about 1900. The introduction of Japanese fishing sampans and gear brought about a rapid growth of the fishery and by 1928 a little over 2 000 t of skipjack tuna were being landed. Nowadays, the Hawaiian fleet, composed of 16 sampans of various sizes, lands about 5 000 t of skipjack tuna annually (Table 1).

Of primary concern at the present time is the expansion and development of the fishery. Purse seining was tried in Hawaiian waters in the early fifties (Murphy and Niska, 1953) and recently another attempt was made (Hawaii Division of Fish and Game and Bumble Bee Seafoods, 1970) but these trials were only partially successful. Thus, pole-and-line fishing with live bait is still the preferred method in Hawaiian waters. At present the industry faces a two-fold problem: first, the need to upgrade the entire fishing fleet; and secondly, the need to increase the supply of live bait.

The Hawaiian skipjack tuna fleet consisted of 28 fulltime vessels during the fifties. Between 1955 and 1971 the demand for tuna increased steadily but even this failed to induce any investment in new fishing vessels and the fleet dwindled to 14 in 1971. The following year, however, reflecting changing enonomic conditions and favourable minimum prices, a 136-gross ton (GT) steel-hulled vessel with a cruising speed of 13.8 kn and a cruising range of 2 000 n mi (3 700 km) joined the fleet (Uchida and Sumida, 1973).

A fluctuating supply of live bait continues to limit the expansion of the skipjack tuna fishery. In 1960-72, the fleet caught an average of 33 659 buckets of nehu (Stolephorus purpureus), a local anchovy that is the preferred bait of the Hawaiian fishermen (one bucket contains about 3.2 kg of nehu). Periodic shortages of bait reduce fishing time. Furthermore, an increase in demand for bait can be expected because rising costs of new vessel construction and operations will undoubtedly force the owners to operate their vessels on a year-round basis.

In an attempt to alleviate the bait shortage, the Honolulu Laboratory of the National Marine Fisheries Service, Southwest Fisheries Center, has investigated a number of options. Among them have been the culture of baitfish and the transporting of live bait from areas of abundance to areas of scarcity. Experiments in transporting live anchovy (Engraulis mordax) from California to Hawaii are continuing at the present time.

2.3 Samoa Islands

Samoa Islands, divided into American Samoa, a U.S. territory administered by the U.S. Department of the Interior, and Western Samoa, an independent sovereign state, are situated between latitude 13° and 15°S and extend in an east-west direction from about longitude 168° to 173°W (Tudor, 1972). American Samoa is comprised of all islands lying east of longitude 171°W. Pago Pago on the island of Tutuila is the principal town. Western Samoa has two large main islands - Upolu and Savaii. The chief town and administrative centre is Apia on Upolu. Pago Pago Harbor serves as a port of landing for foreign longline vessels, now mostly Chinese and Korean, which supply two American canneries with large, subsurface tunas (Van Campen, 1954; Otsu and Sumida, 1968; Uchida and Sumida, 1973).

In an effort to develop a viable pole-and-line skipjack tuna fishery in American Samoa, the Office of Marine Resources (OMR), Government of American Samoa, has launched an investigation to determine temporal and spatial distribution and abundance of skipjack tuna and baitfishes in Samoan waters (Swerdloff, 1974). In October 1971, OMR acquired a new 15.2-m livebait vessel the ALOFAGA. This survey vessel is equipped with four baitwells, fishing racks, ice holds, and has a range of 1 500 n mi (2 780 km) at a cruising speed of 10 kn.

All bait surveys conducted in Samoan waters to date have revealed a scarcity of live bait (Hida, 1970; Uchida and Sumida, 1973; Swerdloff, 1974). According to Hida, baiting was best in Pago Pago Harbor. The results of day and night baiting in Pago Pago Harbor and in Apia Harbor, Western Samoa, are summarized in Table 7.

To determine the seasonal fluctuations and relative abundance of baitfish in Samoan waters, OMR conducted not only visual surveys of all bays and estuaries but also sampled baitfish that collected around a night light. The results are shown in Table 8. In all sampling conducted since August 1970, the annual catch per set has never exceeded 3.0 buckets. Whereas in August-December 1970 Stolephorus sp. predominated in the catch, there has been a steady deterioration of catches of this species in subsequent years.

The scarcity of bait severely handicapped the efforts of ANELA to conduct pole-and-line fishing trials for skipjack tuna in Samoan waters in March-April 1972 (Uchida and Sumida, 1973). ANELA was unable to locate, either day or night, any bait in sufficient amounts in all of the bays and harbours surveyed in both American and Western Samoa. Bait taken in Fiji by ANELA was used to fish in Samoan waters.

The results obtained from the RV CHARLES H. GILBERT, ANELA, AND ALOFAGA survey cruises were ample evidence that skipjack tuna schools occur in Samoan waters in sufficient quantities to support a commercial fishery at least large enough to meet local demands. Waldron (1964) showed that sightings of bird flocks averaged 4.2 flocks per 10-hour period in December-February in 26 hours of scouting. Hida (1970) reported sighting 144 schools in 31 days of scouting and fishing or an average of 4.6 schools per day (Table 9). In March-April 1972, ANELA sighted 25 schools in Samoan waters or an average of 6.2 schools per day (Uchida and Sumida, 1973). Sixteen were identified as skipjack tuna, 1 as kawakawa (Euthynnus affinis); the remainder were unidentified.

Concerning catches, Hida (1970) reported that GILBERT successfully fished 16 schools around American and Western Samoa and caught 1 075 skipjack tuna varying in size from 1.8 to 7.7 kg and 160 yellowfin tuna ranging between 1.1 and 27.2 kg. Twelve of the 144 schools sighted during the GILBERT cruise were estimated to be large, possibly over 45 t (Table 10).

In 4 days of scouting (3 days of actual fishing), ANELA encountered 25 schools. Of these, 21 were pursued and chummed but only 8 were successfully fished. Total catch reached 2 407 skipjack tuna weighing 12.1 t and 33 kawakawa. Catch per day averaged 4.0 t. About half of the catch consisted of fish under 4.5 kg although the fish landed ranged from 2.3 to 11.6 kg. Hooking rate was calculated to be from 0.2 to 2.0 fish per hook-minute.

The results of the nearshore surveys conducted by OMR have shown that a skipjack tuna resource of considerable potential exists in Samoan waters (Swerdloff, 1974). School sightings compare favourably with those of the Hawaiian skipjack tuna fishery and the fishing trials conducted by ANELA showed that skipjack tuna are present in sufficient quantities to support a commercial fishery (Uchida and Sumida, 1973). Shoreside ship-servicing facilities already exist in Pago Pago Harbor. A vital prerequisite, however, is finding the best means of catching the tuna. Naturally occurring bait is scarce but some baitfish, such as the mollie (Poecilia mexicana), could probably be cultured in sufficiently large quantities to keep a small fleet of livebait vessels operating full time (Rodman, 1974).

2.4 Tonga Islands

The Kingdom of Tonga consists of three main groups of islands; in all, there are some 150 islands with a total land mass of 257 mi^2 (660 km^2) (Wilkinson, 1973). With the population growing at an annual rate of 4 percent, there is an urgent need in the Kingdom to find sufficient animal protein food. According to Wilkinson (1973), there have been several attempts in the past to develop the fisheries of Tonga, all with varying degrees of success. At present, there is a Government-owned longliner fishing for subsurface tunas in Tongan waters. The 27-m vessel of Japanese origin has a refrigerated capacity of 45 t. The vessel is manned by a Tongan master and crew, Tongan trainee fishermen and a Japanese masterfisherman.

Trolling for pelagic species is carried out by sailing vessels and good catches of skipjack tuna and kawakawa are possible seasonally. Wilkinson (1973) lists the development of a skipjack tuna fishery as one of the priorities of the Government. He states: "...possible development exists in exploiting the shoals of skipjack and kawakawa, which occur in seasonal abundance in close proximity to the many Tongan islands."

According to Otsu (trip report - Trip to Japan, 3-26 February 1974), the Japan Marine Fishery Resource Research Center conducted bait surveys in Tongan waters in 1972-73. The results of the Tongan survey indicated that, among the 200-300 islets scattered throughout the archipelago, the waters around the northernmost island seemed most promising as a bait site. Using beach seines, the survey vessel caught 20-30 buckets of baitfish per set but mortalities were heavy. The Center concluded that there is very little likelihood of developing a pole-and-line fishery in Tonga.

3. WESTERN PACIFIC OCEAN

It is in the west Pacific Ocean that the most rapid development of skipjack tuna fisheries has taken place in recent years. The thriving skipjack tuna pole-and-line fisheries of Papua New Guinea, Palau Islands, and the Solomon Islands, are typical examples. Other countries are only now beginning to look seriously at their skipjack tuna and bait resources as bases for immediate or future economic development and are seeking financial aid from countries that have established themselves as leading fishing nations in the Pacific basin.

At the Thirteenth Session of the Indo-Pacific Fisheries Council held in Brisbane, Queensland, Australia in 1968, fishery development in the South China Sea in the context of a "South China Sea Fisheries Development and Coordinating Programme" was discussed (Gulland et al., 1974). The purpose was to provide a suitable mechanism for coordinating and implementing fishery development in the South China Sea region. At its Fifteenth Session in Wellington, New Zealand in October 1972, the Council unanimously endorsed a project supported by the United Nations Development Programme (UNDP) and designed to ensure the continuous and steady development of various kinds of fisheries in the region. Among the pelagic fishery resources in the South China Sea that were listed for development and management were the stocks of tuna, including skipjack.

In the west Pacific, Japan has been most active in establishing joint skipjack tuna fishing ventures with developing countries. Figure 3 shows some of the island groups and nations that are discussed in this section.

3.1 Australia

Exploratory fishing trials for southern bluefin tuna (Thunnus maccoyii), and skipjack tuna with pole and line and live bait in Australian waters have been described in Blackburn and Rayner (1951). In 1940, pilchard (Sardinops neopilchardus), and anchovy (Engraulis australis), were carried in a bait tank and used successfully to catch bluefin and skipjack tunas. These early results carried no great significance at that time because bait could not be obtained regularly in large enough quantities.

In 1950-51, a 19-m American-Fijian tuna clipper, SENIBUA, fished experimentally for 4 months in southern New South Wales waters to assess the value of pole-and-line fishing (Anon., 1965). Results were encouraging and the fishing industry took immediate steps to establish a pole-and-line fishery in Australia, but the mainstay of the Australian pole-and-line fishery that developed was the southern bluefin. In March 1963, to exploit the skipjack tuna that appeared on a definite seasonal pattern between Coff's Harbour (New South Wales), and St. Helen's (Tasmania), experiments with monofilament gillnets were begun and the results indicated that skipjack tuna could be taken in sufficient quantities with this gear (Temple, 1963; Anon., 1965). The early gillnet fishery for skipjack tuna was started off Lakes Entrance and Victoria and the vessels operated off the eastern coastal waters of this state. Skipjack tuna in this area were found closely associated with a warm current near the coast. The average weight taken was about 3.2 kg.

The skipjack tuna gillnet vessels varied in size from 9 to 18 m. Although power block was used in the early stages of the fishery, the fishermen later favoured the powered hauling drum and sheaves. The monofilament gillnet originally measured 604 m long and 20 m or 200 meshes deep. Mesh size was 14 cm. Later trials indicated that a net depth of 150 meshes was satisfactory for taking skipjack tuna. Usually, the crew consisted of up to three fishermen.

Heaviest catches of skipjack tuna occurred off Victoria in January and February. Interest in this fishery declined in 1964 when the monofilament gillnets, modified to fish on the bottom, were found to be effective in taking edible sharks which were much higher priced than skipjack tuna.

Thus, marketing difficulties inhibited the further development of the monofilament gillnet skipjack tuna fishery (Anon., 1965). In 1966, a 450-ton former U.S. purse seiner, ESPIRITU SANTO, was purchased by a South Australian firm. A U.S. crew spent a short time instructing Australian fishermen on purse-seining techniques (Anon., 1966). Fishing off Eden in mid-December 1966, ESPIRITU SANTO shot the net twice and netted 29 t of bluefin tuna and a little over 7 t of skipjack tuna. At the 1967 Fisheries Development Conference in Canberra, it was decided that special attention should be focused immediately on the use of purse seines for capturing skipjack tuna (Anon., 1967). The CSIRO Division of Fisheries and Oceanography estimated that prospective catches of skipjack tuna by purse seining could reach 36 300 t (Lorimer, 1970).

Catches of skipjack tuna and other tunas recorded for Australian waters for 1960-61 to 1971-72 are given in Table 11.

3.2 Fiji Islands

The Fiji group comprises 320 islands of various sizes between latitude 15° and 22°S and longitude 177°W and 175°E (Tudor, 1972). Two of the largest islands are Vanua Levu and Viti Levu on which Suva, the present capital, is located. The former capital, Levuka, on the island of Ovalau, serves as a port for foreign longline fishing vessels unloading frozen tuna for trans-shipment to canneries in the United States and Japan (Uchida and Sumida, 1973).

In 1971, the Food and Agriculture Organization of the United Nations, in accordance with its programme to determine the feasibility of fishery development among developing nations, scheduled a skipjack tuna resource survey in Fijian waters. This survey, known as the FAO/UNDP Local Tuna Project in Fiji, was conducted out of Suva, Viti Levu Island (U.S. NMFS,1971b). A major Japanese fisheries firm was commissioned to undertake the survey and to provide technical training to the local fishermen. The project, originally scheduled to last one year, was extended and the tuna survey was not completed until July 1973 (U.S. NMFS, 1973l).

In a paper submitted to the South Pacific Commission meeting on fisheries in Suva, Fiji in July 1973, it was reported that the vessel used by the project was of Japanese origin and typical of pole-and-line vessels operating in the west Pacific (Anon., 1973). The 40-ton SHINPO MARU was powered by a 250-hp diesel engine and cruised at 8 kn. Its operating range was 1 725 n mi (3 200 km). Three baitwells with natural circulation had a carrying capacity of about 85 buckets (bucket holds 1.8 kg of baitfish). Fishholds along both sides of the baitwells could hold 12 tons of iced fish. Crew consisted of four key personnel provided by the contractor - the vessel master, fishing master, chief engineer, and chummer - and 12 native Fijian trainees.

Bait and fishing operations have been described in detail by Anon. (1973) and Lee (1973). Briefly, three bait species were very abundant and constituted the major portion of the bait captured during the day with a beach seine. These were, in order of their predominance in the catch, sardine (Herklotsichthys punctatus), silverside (Pranesus pinguis), and anchovy (Thrissina baelama). Day bait was captured in shallow water along the beach with a Hawaiian-type beach seine measuring 73 m long and 4 m deep. The captured baitfish were then transferred to a bait receiver which was towed to the vessel for transfer to the baitwells. The sardine and silverside, making up 81 percent of the 1972 day bait catch, were hardy and withstood the transfer from seine to bait receiver to baitwell without significant mortalities. The anchovy was less vigorous; they scaled easily and mortalities were high. They constituted 19 percent of day bait catch.

At night, artificial light was used either above water or submerged to attract baitfish. When set above water a 1 000-W lamp was used and usually a liftnet was used to capture the bait congregated under the light. When a submerged light was used, lamp size was 500, 1 000, or 1 500 W. For this method of night baiting, a stick-held blanket net was used exclusively.

Night bait, captured in appreciable quantities, included the small round herring (Spratelloides delicatulus), sardine (Sardinella sirm), silverside (Allanetta ovalaua), and small anchovy (Stolephorus buccaneeri). Other species were taken in smaller quantities. Hardiest among the bait captured at night were sardine, silverside, mackerel (Rastrelliger kanagurta), bigeye scad (Selar crumenophthalmus), leatherskin (Chorinemus tol), Caranx sp., sardine (H. punctatus), and silverside (P. pinguis).

Baitfish catch amounted to 2 500 buckets in 1972. With better knowledge of the local baiting sites and increased efficiency in capturing bait the crew of the SHINPO MARU caught 4 000 buckets of bait in January-June 1973. Four baiting sites produced the bulk of the bait catch in 1972 - Momi Bay off Viti Levu, Kia Island, Savu Savu Bay off Vanua Levu, and Ono Island. In 1973, Soso Bay off Kandavu Island produced nearly half and Ovalau Island about a quarter of the bait catch.

On the exploratory cruise of ANELA, NMFS observers on board noted that bait was plentiful at Kia Island (Uchida and Sumida, 1973). In two baiting operations, the crew of ANELA spent 1.7 hours baiting and in three sets caught 269 buckets (3.2 kg of baitfish per bucket) of bait, averaging 158.2 buckets per hour and 89.7 buckets per set. About 75 percent of the bait was sardine (H. punctatus), and the remainder was silverside (P. pinguis).

School sightings were numerous in Fijian waters. Lee (1973) reported that on 29 exploratory fishing cruises made in 1972, 103 days were devoted to scouting and fishing for tuna schools. There were 653 sightings of fish schools, 38 percent of which were identified as skipjack tuna (Table 12). The average sighting per day was 6.3 schools. ANELA also found

numerous bird flocks during its short trial fishing period in Fiji, sighting an average of 5.1 schools per day (Uchida and Sumida, 1973). The bird flocks associated with the fish schools were large: 56 percent were composed of 101-500 birds with noddy terns predominating.

In 1972, SHINPO MARU caught 44.7 t of fish of which about 81 percent, by weight, was skipjack tuna (Lee, 1973). The catch was up considerably in 1973 - in 6 months, from January through June, 96.2 t of fish were landed. The catch made by ANELA was also very impressive. In 2 days of intensive fishing, ANELA landed 19.1 t of skipjack tuna or an average of 9.6 t per day.

The Fisheries Division of the Department of Agriculture and Fisheries has acquired a new tuna research vessel, TUI NI WASALIWA (Anon., 1974a). Manned with a crew experienced in pole-and-line fishing operations, the vessel caught 18 t of skipjack tuna in 5 days of fishing or 3.6 t per day.

Lee (1973) reported that the size of skipjack tuna taken in Fijian waters ranged from 0.4 to 9.9 kg, a large percentage weighing less than 5 kg. ANELA encountered many schools of small fish in Fijian waters. The skipjack tuna landed ranged from 1.2 to 4.5 kg and averaged 2.9 kg (Uchida and Sumida, 1973).

The results of the FAO/UNDP Local Tuna Project and of the brief survey of ANELA strongly indicate that skipjack tuna schools occur in Fijian waters in sufficient numbers to support a small commercial fishery and the Fiji Islands, as a future fishery base for a commercial skipjack tuna fishing operation, has attracted the attention of tuna fishing and packing firms of other countries (U.S. NMFS, 1973k). A Canadian-British firm has sent a team to Fiji to promote fishery development plans which include the establishment of a fishing base at Lautoka. Also included are the employment of South Korean vessels for fishing and the construction of a cannery and cold storage. Other firms, including two U.S. tuna packers and several Japanese and South Korean firms, have also submitted fishing development plans.

3.3 Gilbert and Ellice Islands

The Gilbert group of islands, situated along the equator between latitude 4°N and 3°S and longitude 172° and 177°E, is composed of 16 islands. The Ellice group, between latitude 5° and 10°S and longitude 176° and 180°E, is composed of nine islands (Figure 3).

No commercial fishery for tuna exists in the Gilbert and Ellice Islands. Native fishermen, however, report that skipjack and yellowfin tunas are caught all the year round (Hinds, 1969). Skipjack tuna vary in size from 1.8 to 5.4 kg whereas yellowfin tuna vary between 1.4 and 36.3 kg. Despite the presence of both skipjack and mixed skipjack-yellowfin tuna schools in waters surrounding the Gilbert and Ellice Islands, the seasonality of these tuna schools is not known.

Hinds (1969) stated that the surface tuna schools around the Gilbert and Ellice Islands are fished by trolling lines, although the Polynesian method of pole-and-line fishing with a mother-of-pearl shell lure is practised in the Ellice Islands and the southern Gilbert Islands. Catches are small and usually divided among relatives and friends of the fishermen; only the surplus is sold. A marked increase in catches resulted when canoes were replaced with outboard-powered 3.6-m fibreglass hulls.

Fishing the tuna schools with pole and line and live bait is also a distinct possibility. Hinds (1969) reported that present in the lagoon at times are large schools of small fish, such as bari (Selar sp.), tarabuti (Harengula sp.), and kimokimo (Decapterus sp.), that could be used as live bait. Their seasonality and abundance, however, is uncertain.

3.4 Indonesia

The Republic of Indonesia consists of two chains of islands located in and surrounded by the Pacific and Indian Oceans. The southwest chain is made up of Sumatra, Java, Lesser Sunda Islands, and the western half of Timor (Tudor, 1972). The northeast chain consists

of a part of Borneo, Celebes Archipelago, Molucca Archipelago, and Tanimbar Archipelago. The Republic of Indonesia also administers the province of West Irian.

Because of favourable environmental conditions, Indonesia has considerable fisheries resources (Zachman, 1973). Some parts of Indonesian waters are, at present, only lightly exploited. Substantial harvests can be anticipated from these areas, particularly those offshore where there is a high pelagic resource potential. Skipjack tuna, mackerel-like fishes, clupeids, round scads, and squids constitute part of the main pelagic resources. Subsurface tunas also occur in Indonesian waters. Zachman (1973) reported that, according to the Master Plan of Fisheries Development, the skipjack tuna stocks in Indonesian waters are estimated at 150 000 t.

The first fishery resource survey in Indonesian waters was carried out under the sponsorship of the UNDP in November 1969 (U.S. NMFS, 1971b). Funds for the survey, made available to Indonesia by the Government of the Netherlands through the United Nations, were intended for agricultural and fishery development (Katsuo-Maguro Nenkan, 1973). A base was established in Sorong, West Irian and Japanese fishing firms were contacted to determine their interest in carrying out the survey.

Two Japanese firms, one with a background in fishing and the other in trading, joined forces and were selected by UNDP to begin exploratory fishing (U.S. NMFS, 1971). Table 13 shows that the fleet consisted of five 110-GT pole-and-line vessels, four 10-ton bait-catcher vessels, and a 700-ton freezer mothership (Katsuo-Maguro Nenkan, 1973). The results of the 18-month survey, which began in November 1969 and ended in March 1971, were not encouraging (U.S. NMFS, 1971, 1971b). As a result, the Japanese firms entered into a second agreement to conduct exploratory skipjack tuna fishing in the Molucca Sea from a base in Ternate, Halmahera Island from April to September 1971 (Table 13). Catches averaged 3.5 t per vessel per day (Katsuo-Maguro Nenkan, 1973). At the end of the survey, which revealed that catches of more than 3 t per vessel per day were possible, a joint venture was established with 80 percent capitalization by the Japanese. Included in the provisions of the joint-venture agreement was the construction of a 500-ton capacity cold storage equipped with a 5-ton icemaking plant.

Other Japanese firms also showed strong interest in the skipjack tuna resource in Indonesian waters (Table 13). Plans were laid to establish fishing bases in Butung Island in the Banda Sea (U.S. NMFS, 1971e), at Pandiang on Sumatra Island with fishing operations concentrated in the Sunda Strait (U.S. NMFS, 1971f), and at Kendari on Celebes Island (U.S. NMFS, 1972b). Exploratory fishing was also conducted along the west coast of Sumatra Island bordering the Indian Ocean and in the Makassar Strait and the Flores Sea. The results of these latter two surveys, however, were disappointing (Katsuo-Maguro Nenkan, 1973).

Information on the operational aspects of the Indonesian skipjack tuna fishery is sparse. In the vicinity of Sorong, West Irian, the anchovy is caught by stick-held liftnets (bōuke ami) and used in livebait fishing (Katsuo-Maguro Nenkan, 1973). The vessels usually operate within a radius of about 250 n mi (460 km) of their home base. Data on annual catches of skipjack tuna are given in Table 2.

3.5 Republic of Korea

One of the countries on the periphery of the west Pacific, the Republic of Korea has a long tradition as a fishing nation. Until recently, however, Korean fisheries were usually confined to inland and near-coastal waters (Anon., 1973a). In the late fifties and early sixties, the Government intensified its effort to modernize the marine industry and the greatest expansion was concentrated in the offshore and deepsea fisheries. An example of Korea's bid to get a larger share of the offshore marine resources can be seen in the South Pacific albacore fishery operating out of a base in American Samoa. Here, the fishery was conducted exclusively by Japanese vessels in the early years but, from about 1958, more and more vessels from the Republic of Korea and Taiwan have been involved (Otsu and Sumida, 1968).

With no appreciable increase in catches of subsurface tuna possible, Korea in recent years have turned to the development of a skipjack tuna fishery. Skipjack tuna fishing is new to its fishermen (Anon., 1973a). Therefore, the Government has sought assistance from the FAO/UNDP.

Reports indicate that a Korean firm and a United States firm formed a joint skipjack tuna fishing venture in January 1972 (U.S. NMFS, 1971h). Construction of eight pole-and-line vessels in the Republic of Korea was scheduled and plans called for operations in the equatorial Pacific off the Philippine and Marshall Islands. Also included was construction of a tuna-packing plant in Masan. To support this plant, the Government of Korea requested that the Distant-Water Fisheries Training Centre, financed by UNDP, train pole-and-line fishermen (U.S. NMFS, 1972k). Training in pole-and-line fishing was also scheduled aboard Korean research vessels (U.S. NMFS, 1972a).

To conduct skipjack tuna fishing surveys, Korea's Government took delivery of two skipjack tuna survey vessels built in Japan (U.S. NMFS, 1972k). The 200-GT vessels have 1 000-hp main engines and an overall length of 35.6 m. Shipboard installations include a brine freezing system and a seawater circulating livebait well.

In January 1973 it was also reported that a fishermen's cooperative, the Central Federation of Fisheries Cooperatives (CFFC), planned to purchase eight 400-GT skipjack tuna vessels with a U.S.$ 13.3 million loan from the Asian Development Bank (Anon., 1973a).

These vessels will become part of a fleet of 20 skipjack tuna vessels that Korea hopes to acquire by 1976.

The training of deck and engine room officers has also received wide attention (Anon., 1973a). Under a UNDP-assisted programme, the FAO-administered Coastal Fishing Training Centre at Pusan has expanded its training programme to include engineers, officers, fishermen, and deckhands needed by the skipjack tuna fleet. The Coastal Fishing Training Centre and the Deep-Sea Fishing Training Centre, both originally established in Pusan under two separate FAO/UNDP projects, have been combined to form the Korean Fishing Training Centre, one of the largest and best equipped institutions of its kind in the world.

At least one Korean exploratory skipjack tuna fishing cruise has been completed. Fishing off the Bonin Islands, the Korean fishermen gained confidence in their ability to fish with pole and line and live bait (U.S. NMFS, 1973f). Forty five metric tons of skipjack tuna and albacore were landed.

3.6 New Hebrides and New Caledonia

New Hebrides consists of an incomplete double chain of roughly 80 islands extending from northwest to southeast for 450 n mi (834 km) (Tudor, 1972). New Caledonia lies south of New Hebrides and about 700 n mi (1 300 km) east of the Queensland coast of Australia.

A tuna fishing industry based at Palekula, which is southeast of Espíritu Santo, was established in 1957 (Tudor, 1972). The operating company, which has American, British, French, and Japanese capital, obtains tuna from the Japanese longline vessels based at Palekula. Here facilities also exist for slipping and repairing fishing vessels.

Water surrounding the New Hebrides and New Caledonia has been surveyed by ORSOM III (Angot, 1959). The results indicated that trolling gear was the most suitable for taking skipjack and yellowfin tunas. Yellowfin tuna were usually taken just outside the reef and skipjack tuna catches farther offshore. Angot stated that trolling catches of the ORSOM III were quite satisfactory. A commercial trolling fishery has been established in New Caledonia and the catch is sufficient to supply the demands of the Noumea market. Annual catches from New Hebrides are given in Table 2.

Angot (1959) concluded from the survey that waters surrounding New Caledonia were sufficiently productive to support a small-scale troll fishery but not a pole-and-line fishery. Very few surface tuna schools were sighted during the survey period. Furthermore, small fish that could be used as live bait were not found in sufficient quantities to permit extensive pole-and-line fishing.

In 1973, it was reported that the 190-ton Japanese pole-and-line vessel AKITSU MARU 20, was chartered by the semi-government Marine Fishery Resource Research Center of Japan to conduct surveys of baiting grounds in the South Pacific (U.S. NMFS, 19731). In late November, AKITSU MARU caught 35 buckets of sardines and 0.9 t of skipjack tuna east of New Caledonia. Thirty six buckets of sardines were also taken in December near latitude 20°-22°S and longitude 165°-167°E. Otsu (trip report: Trip to Japan, 3-26 February 1974) reported that lift-nets used by the survey vessel produced catches of 50-100 buckets of bait per night. The baiting grounds were usually from 1 to 3 km offshore. Exploratory fishing resulted in poor catches, unlike catches reported from the previous year. The Center concluded that New Caledonia has definite possibilities for the development of a pole-and-line skipjack tuna fishery.

3.7 New Zealand

Of the nine species of tuna and tuna-like fishes found in New Zealand waters, four are readily available to the local vessels (Robert, Baker and Slack, 1972). Only two species (albacore and skipjack tuna), however, constitute the bulk of the catch. The other two (southern bluefin tuna and yellowfin tuna) appear occasionally in large numbers, but make up only a small percentage of the annual landings.

Off New Zealand's coast, skipjack tuna usually appear in summer and autumn. They are usually caught by gillnetting, trolling, and pole-and-line fishing. The average size varies from 3.6 to 4.5 kg although pole-and-line fishing has produced fish that weighed from 6.3 to 8.2 kg.

Roberts et al. (1972) reported that experienced fishermen from both Japan and the United States, working in New Zealand, have demonstrated that pole-and-line fishing is at least partially successful for taking several species of tuna. In the Bay of Plenty, small vessels have successfully fished with pole and line and live bait which was carried to sea in modified 44-gal (166-l) drums.

In February-March 1972, a pole-and-line tuna fishing survey was conducted in New Zealand waters (Webb, 1972). Among the goals of the survey were assessment of the potential of Tasman Bay pilchards and anchovies as baitfish and investigation of tuna potential offshore using longline, pole-and-line, and troll gear.

The results of the survey suggested that pole-and-line fishing would be more practical in warmer waters to the north of the Bay of Plenty rather than in the cooler southern waters (Webb, 1973). Fish in southern New Zealand waters were more agile and less inclined to school. Furthermore, weather conditions were unstable and unpredictable, thereby interfering with pole-and-line fishing operations.

The survey also revealed that baitfish were found in sufficient quantities for a limited, but profitable, bait venture (Webb, 1972a). They were distributed throughout Marlborough Sounds (down to the lower reaches) and Tasman Bay. It was estimated that the potential catch could reach 1 000 t. Baiting was possible in all untouched areas. With five baiting methods available (purse seine, lampara, bouke net, beach seine, and trap nets) weather was not a serious limiting factor in Marlborough Sounds but it hindered baiting activity in Tasman Bay.

The New Zealand Marine Department has continued to research new techniques for catching tuna in order to promote a tuna export trade. Avery (1970, 1970a) described an unusual series of experiments where monofilament gillnets were used in conjunction with sonic and other lures to capture skipjack tuna. Briefly, signals associated with the presence of tuna,

such as the transmission of various dolphin signals and thrashing and fear noises of baitfish under attack were recorded. A broad sea front of about 1 n mi (37 km) was covered with sono buoys to detect the presence of schooling tuna. The recordings of the signals were then transmitted in areas where tuna were scattered in order to attract them to the point of signal, which in fishing strategy would be to the nets or longlines.

In December 1969–May 1970, the New Zealand Marine Department supplied the Whakatana commercial fishing fleet with gillnets and other equipment. Fishing with gillnets and sonic lures produced a catch of 64 t. The efforts of this fleet established the prospect of future gillnetting for skipjack tuna, possibly in other areas. The 1970–71 programme of the Marine Department emphasized further experiments in tracking and attracting tuna with sonar equipment.

3.8 Papua New Guinea

New Guinea, the world's largest defined island, consists of three territories – the Trust Territory of New Guinea, Territory of Papua, and Territory of West Guinea or West Irian (Tudor, 1972).

The Trust Territory of New Guinea is made up of the northeastern part of the New Guinea mainland together with six large islands and their numerous small neighbours. The Territory of Papua consists of the southeast section of the New Guinea mainland and adjacent islands.

In 1972, Pownall wrote: "Exploitation of skipjack and yellowfin tuna in the Bismarck and Solomon Seas promises to develop into the Territory's most profitable fishery." The development of the Papua New Guinea fishery for skipjack tuna and the associated bait fishery has been documented by Kearney (1973). Briefly, the commercial fishery for skipjack tuna in Papua New Guinea was started in March 1970 by a joint Japanese–Australian enterprise based in the northeastern Bismarck Sea (U.S. Bureau of Commercial Fisheries, 1970; Kearney, 1973). In the first year of operation, three 39-ton vessels working out of Kavieng, New Ireland averaged less than the break-even catch of 5 t per vessel per day. But fishing conditions appeared to be good and all indications were that the catch could be increased. By 1971, three Japanese firms were conducting exploratory skipjack tuna fishing in Papua New Guinea. Details of the joint-venture operations may be found in Katsuo-Maguro Nenkan (1973).

Catches fell below expectation in late 1971 and early 1972. Among the problems that plagued this newly established fishery were fluctuations in the availability of skipjack and of baitfish. Based on results of the first year of operation, several recommendations evolved. Among them were to continue development of skipjack tuna fishing and baiting grounds and to establish a skipjack tuna canning plant providing employment to local residents (U.S. NMFS, 1971g).

In spite of the difficulties encountered by the Kavieng operation, other joint ventures were established. A second joint venture, established initially in Manus, later shifted to Madang (Katsuo-Maguro Nenkan, 1973); another started in Rabaul at about the same time. By 1972, three Japanese–Australian joint-venture corporations were actively engaged in skipjack tuna fishing. They joined an American canning firm and a Papua New Guinea investment corporation to establish the Papua New Guinea Canning Company (PNGCC). A summary of these joint-venture operations is given in Table 14.

Catcher boats fishing in Papua New Guinea were built either in Japan or in the Ryukyu Islands (Okinawa) and crewed by Okinawan fishermen (Kearney, 1973). Each operation involves one or more motherships to receive the catches. Catcher boats vary in size; most are about 39 GT, but some are as large as 192 t (U.S. BCF, 1970; U.S. NMFS, 1972i; Table 14).

According to Kearney (1973), all fishing operations in 1970–71 were confined within or on the boundaries of the Bismarck Sea. The 1970 catch was restricted entirely to the northeastern sector but the expansion of the fishery in 1971 broadened the area of operation to include the eastern and southwestern Bismarck Sea. Catches from these areas are shown in Table 15. Of the three areas, the eastern sector was most productive and catches were highest from areas within 20 n mi (37 km) of the large land masses.

In 1970, with only one joint-venture company in operation, the catches of skipjack and other tunas, including yellowfin tuna, kawakawa (Euthynnus affinis), and frigate mackerel (Auxis thazard), reached 2 430 t (Kearney, 1973). Monthly landings for March-August and November-December 1970 are given in Table 16. With three Japanese firms operating in 1971, the catch increased sevenfold to 17 002 t (Table 16), but decreased to 13 124 t in 1972 (Kearney, 1974). The annual landings for 1973 have been estimated at about 28 000 t.

The seasonal nature of the fishery can be seen in the montly landings in 1971, with peak catches occurring in June-August and low catches in November-December (Table 16 and Figure 4). The average catch per vessel per day, plotted in Figure 4, varied from a high of 6.5 t in June to 2.3 t in December.

According to Table 15, skipjack tuna caught in the southwestern Bismarck Sea were usually largest, with monthly averages ranging from 3.6 to 5.1 kg. The northeastern Bismarck Sea usually had the smallest fish; they ranged from an average of 3.2 to 3.9 kg. Fishes caught in the eastern Bismarck Sea were usually intermediate in size compared to fishes from the northeastern and southwestern sectors.

Bait is available in sufficient quantities to maintain a sizable tuna industry in Papua New Guinea (Kearney, 1973). Of 300 or more different species collected from bait stations, about 10 are considered suitable as live bait for skipjack and other tunas (Kearney, 1974). Bait surveys by Japanese research vessels also indicated the presence of a number of species that possess the potential of a good baitfish; these species belonged to the families Engraulidae, Clupeidae, Dussumieridae, and Atherinidae (Kikawa, 1971).

From the inception of the fishery in March 1970 until May 1971, bait was caught during daylight by the "oikomi ami", a set net with a bag, into which fish are driven by swimmers or divers (Kearney, 1974). This bait was predominantly Gymnocaesio gymnopterus, but also caught was Pterocaesio pisang (Kearney, Lewis and Smith, 1972). Both G. gymnopterus and P. pisang are relatively abundant and tolerate handling without high mortalities.

From May 1971, baiting operations were conducted exclusively at night with bright, submerged lights and stick-held liftnets (bōuke ami) (Kearney, 1973). Stolephorus devisi was the dominant species taken by this method. This species, although excellent for skipjack tuna fishing is very delicate and difficult to transport.

The potential for future expansion of the Papua New Guinea skipjack tuna fishery appears to be excellent. The importance of baitfish in this pole-and-line fishery cannot be overemphasized and, according to Kearney (1974), the results of baitfish research have indicated that the bait resource present in Papua New Guinea waters appears adequate for considerable expansion of the fishery. Likewise, the tuna resource in waters adjacent to Papua New Guinea is large. In 491 hours of aerial surveys, an estimated 37 469 t of pelagic fish, not including bait, were observed (Kearney, 1974). The aerial survey not only revealed possible new fishing areas, but also good concentrations of species other than skipjack tuna in some areas.

3.9 Philippine Islands

The Republic of The Philippines, comprising a vast cluster of more than 7 000 islands, extends from north to south about 1 000 n mi (1 850 km) and from east to west about 625 n mi (1 150 km) (Tudor, 1972).

The early history of the pole-and-line fishery established for skipjack and yellowfin tunas in The Philippines has been adequately described by Domantay (1940, 1940a). Briefly, four vessels ranging from 24 to 40 GT were employed to fish primarily for skipjack tuna, most abundant of the tunas found in southern Mindanao, and yellowfin tuna. The area of operation included the Sulu Sea, Celebes Sea, and off Zamboanga.

Several species of Sardinella found along Zamboanga and Davao provinces were used as live bait. S. leiogaster and Scutengraulis mystax were usually preferred over other species because of their hardiness. Bait was caught in a net, locally called "sangab", which is set against the current. Several dugouts with lights attracted the bait.

Fishing at sea was the same as in many other places with sea birds guiding the fishermen to surface tuna schools. Actual fishing time on one school usually lasted 10 minutes, although it varied widely. Ice was used to preserve the catch. The skipjack tuna caught in Philippine waters never exceeded 5 kg; those caught between October and April were usually larger, weighing not less than 3 kg. Yellowfin tuna, on the other hand, were as large as 30 kg.

It does not appear that the pole-and-line fishery as described by Domantay (1940, 1940a) has changed significantly over the years. There has been, however, a recent resurgence of interest in expanding the pole-and-line fishery by securing venture capital from foreign sources. A fishery firm at Jolo, Sulu Island reportedly was seeking Japanese firms for a joint skipjack tuna fishing venture (U.S. NMFS, 1972h). Upon approval by the Japanese Government for a Japanese company to participate in this venture, it was expected that four 10- to 15-ton purse seiners would start skipjack tuna baitfish surveys in the Sulu Sea. If the baitfish resource proved adequate, pole-and-line vessels were to be chartered from Japan.

In 1973, two more Japanese firms and a Philippine corporation agreed to form a joint fishing venture based at Zamboanga, Mindanao Island (U.S. NMFS, 1973i). According to the agreement, the Japanese will provide two 39-ton catchers and a 200- to 300-ton carrier. Fishing will be concentrated in the Sulu Sea, with a first-year goal of 1 800 to 2 300 t of skipjack tuna. The catch will be processed locally and exported to Japan.

Under a UNDP-SF Deepsea Fishing Development Project, a livebait masterfisherman from France was appointed to train Filipino fishermen in pole-and-line fishing (Reyes, 1972). The project vessel, MV HASA-HASA was to be used to train the crew in catching and keeping bait and in chumming and working skipjack and yellowfin tuna schools. The project was expected to demonstrate to the Philippine fishing industry that pole-and-line fishing could be refined and further developed into an efficient means of taking skipjack and other tunas.

Table 1 shows the catches of skipjack tuna from Philippine waters in 1967-73. They varied widely from 200 t in 1970 to 3 500 t in 1972. Not all the skipjack tuna were taken by pole and line. In 1970, for example, the Philippine Fisheries Commission (1970) included in their statistics catches of skipjack tuna as follows: bagnet - 79 440 kg; hook and line - 4 000 kg; purse seine - 18 000 kg; otter trawl - 13 720 kg; and round-haul seine - 7 200 kg.

3.10 Ryukyu Islands

The Ryukyu Islands form an arc-shaped archipelago extending from southern Kyushu in Japan southwesterly toward Taiwan. The historical development of the pole-and-line skipjack tuna fishery in the Ryukyu Islands has been discussed by Shapiro (1949) and Isa (1972).

Skipjack tuna is one of the most important species taken in the Ryukyu Islands. Isa (1972) estimated that, annually, catches of skipjack tuna accounted for as little as 14 percent and as much as 69 percent of the total fish landings in the Ryukyu Islands.

Briefly, the Ryukyuan skipjack tuna fishery employs small vessels of wooden construction that vary from 10 to 53 GT (Isa, 1972). The vessels either buy live bait from independent bait fishermen or spend a day at the baiting grounds catching enough bait for a day's fishing. The common bait species used throughout the Ryukyu Islands are given in Table 17. The amount of bait used for 1966-67 is shown in Table 18. Ryukyuan fishermen generally use the "drive-in" method to catch bait but night lighting for bait is also employed to some extent.

Skipjack tuna fishing is highly seasonal. Usually the largest catches occur in July (Table 19) and the smallest catches in March (Isa, 1972).

The Ryukyuan fishery for skipjack tuna has been beset with problems of declining effort and wide fluctuations in catches. The vessels have experienced difficulty in obtaining sufficient quantities of bait and in keeping bait alive for extended periods. Furthermore, the small Ryukyuan vessels are incapable of fishing along the Ryukyu Islands chain as the Japanese

vessels do. The result is that Ryukyuan vessels are unable to shift their operations with the movement of the fish on the fishing grounds. These are some of the reasons that there has been no significant growth of this fishery.

Isa (1972) pointed out that the Ryukyu's skipjack tuna fishery will not develop or expand under the present system of operation and management. There are, however, plans to obtain vessels in the 200-ton class and to operate them throughout the year in the northwestern Pacific. Bait could be obtained locally and from other sources. There are also plans to develop multi-purpose vessels capable of operating not only in the skipjack tuna pole-and-line fishery in the summer, but also in the tuna longline fishery in the winter.

Skipjack tuna landings in the Ryukyu Islands in 1921-70 are given in Table 1.

3.11 Solomon Islands

The Solomon Islands consist of 10 large islands or clusters of islands (Tudor, 1972). They lie in a double chain from northwest to southeast and extend over 900 n mi (1 700 km) of ocean. In the Solomons fishery development is being advocated to strengthen the economic base (Katsuo-Maguro Nenkan, 1973). The local Government negotiated with Japanese interests to begin a fishing survey in waters around the Solomons as a preliminary step to the establishment of a joint-venture fishing operation.

In 1971, three tuna motherships were dispatched to fishing bases established in Shortland Island, Gizo, and Tulagi (Katsuo-Maguro Nenkan, 1973). The mothership purchased skipjack tuna caught by 39- and 47-ton Okinawan catcher boats. From five boats in the initial phase of fishing in the autumn of 1971, the fleet grew rapidly to a maximum of 15 boats in the spring of 1972 (U.S. NMFS, 1972i).

The early period of the fishery was not without problems. The boats experienced good fishing the first six months of operation, averaging 5 t per vessel per day, but catches declined thereafter and bait was in short supply (Katsuo-Maguro Nenkan, 1973). By mid-1972, the Japanese firm engaged in exploratory fishing reported that catches of their vessels were below expectation (U.S. NMFS, 1972i). The majority were landing between 50 and 60 t per month with high performers catching 70-80 t and low-performing vessels only 20-30 t per month. Catches continued low until the spring of 1973, improving gradually thereafter. By August each vessel was averaging 4-5 t per day (U.S. NMFS, 1973g). Also, larger skipjack tuna moved into the fishery. Whereas 70 percent of the fish caught in July averaged 3.2 kg, most of those taken in August averaged 3.5-4.0 kg.

Despite unstable conditions, the Japanese decided to enter into a joint venture with the local Government (U.S. NMFS, 1973a). The joint-venture plans, which became effective in the spring of 1973, called for employing 12 pole-and-line vessels and 1 refrigerated carrier operating out of Tulagi and New Georgia Islands during the first year. By mid-1973, a tuna cannery with a daily production capacity of 1 300 cases was completed on Tulagi (U.S. NMFS, 1973b, 1973h). Plans also call for an increase in output to 2 000 cases a day within the next 4 years and a fleet size of 23 vessels in 5 years. Additionally, a 600-ton capacity cold storage was built on Tulagi and 300-ton capacity storages were planned for other places. The joint venture was organized so that the local Government invested 25 percent and retained the right to increase its share later. Also, over a period of 10 years, the fishing company and vessels, now in Japanese control, will revert to local control.

In 1971-73, the Solomon-based fleet landed between 4 707 and 7 643 t of skipjack tuna (U.S. NMFS, 1973j, 1974; R.E. Kearney, Department of Agriculture, Stock and Fisheries, Konedobu, Papua New Guinea, personal communication). The cannery at Tulagi has been processing the fish, packing about 200 cases per day. The outlook is optimistic. The cannery, employing native workers, may begin full-scale operation earlier than the original schedule of 1977-78. The projected catch for 1974 is 8 000 t based on the catches of about eight vessels.

3.12 Taiwan

Taiwan, situated off the east coast of the People's Republic of China, has made remarkable progress in developing its tuna longline fishery; but, like many countries presently exploiting the large, subsurface tunas, this fishery is faced with the problem that the large tuna species in all oceans are being exploited to the limit of their potential and that continued fleet expansion will not bring about a significant increase in the catch (U.S. NMFS, 1973f). Therefore, plans have been laid to enter the skipjack tuna fishery. According to a report, it is planned to build in Taiwan 50-GT skipjack tuna fishing vessels (U.S. NMFS, 1973f).

3.13 Trust Territory of the Pacific Islands

The U.S. Trust Territory of the Pacific Islands, also referred to as The U.S. Trust Territory of Micronesia, is comprised of the Caroline, Marshall, and Mariana Islands. Within a vast area of about 3 million mi^2 (10.3 million km^2) there are 2 100 islands (Rothschild, 1966).

The skipjack tuna resources of the Trust Territory region have a long history of exploitation. The pre-second world war fishery has been described in several publications (Smith, 1947; Shapiro, 1948; Wilson, 1965; Uchida, 1970). Briefly, the Japanese fishery for skipjack tuna in Trust Territory waters began in the early twenties. By the mid-twenties, information gathered by Japanese research vessels indicated that important potential for skipjack tuna fishing existed in the Trust Territory. The result was a rapid expansion of the fishery in the thirties. A peak in production, which occurred in 1937, was attributed to the operation of an unusually large number of fishing vessels (Table 20).

The outbreak of the second world war halted commercial production of skipjack tuna from the Trust Territory region. Although longline fishing for subsurface tunas was resumed soon after the war, pole-and-line fishing for skipjack tuna was not revived until 1964 (Wilson, 1963; Uchida, 1970). In that year, a United States firm established a 1 500-ton capacity freezer-storage plant at Malakal Harbor in Palau and operated a fleet of Japanese and Okinawan skipjack tuna vessels.

In April 1969, a Micronesian Agreement was concluded between Japan and the United States (U.S. NMFS, 1971c, 1972j). Under the provision of the agreement, Japanese fishing vessels were allowed to call at Truk and Ponape to purchase supplies and for rest and recreation (U.S. NMFS, 1972j). The Japanese fishing industry hoped to have its Government's survey mission study port facilities as well as the feasibility of obtaining live bait for pole-and-line fishing in that region.

By 1971, Japanese firms were actively pursuing the establishment of joint skipjack tuna fishing ventures in Micronesia. Two Japanese firms, negotiating an agreement with a Trukese businessman, began fishing out of Truk Island with two pole-and-line vessels in the 20- to 25-GT class accompanied by one mothership (U.S. NMFS, 1971d). Two other firms jointly negotiated an agreement with the local Government in Ponape and began operations with one mothership and three 30-ton skipjack tuna fishing vessels. Fishing reportedly began in late July 1971. Soon afterwards, a third Japanese firm, which was already operating eight vessels from a base in Rabaul, New Britain in New Guinea, proposed another joint venture in Ponape (U.S. NMFS, 1971e). In early 1972, the Ponape District Fishery Corporation agreed to form a partnership with still another Japanese firm. A five-man Japanese team, dispatched to survey Ponape's baitfish resources, found the outlook for skipjack tuna fishery development very favourable (U.S. NMFS, 1972c). Under the joint-venture agreement, four 39-GT skipjack tuna vessels and one 1 000-ton refrigerated mothership were to begin fishing operations in June 1972. The catch, according to the report, was to be shipped to Japan. Future plans include the construction of a cold storage and processing plant at Ponape.

By mid-1973, restrictions regarding the entry of foreign vessels into Micronesian ports were eased. The Congress of Micronesia passed legislation that opened seven Micronesian ports to foreign fishing vessels for the purpose of supplying fuel, water, and food as well

as providing rest and recreation to crew members (U.S. NMFS, 1973e). The seven ports are: Tanapag, Saipan; Tomil, Yap; Malakal, Palau; Moen, Truk; Ponape, Ponape; Jabor, Jaluit; and Darrit, Majuro.

Foreign vessels fishing in and around Micronesia include those from Japan, Republic of Korea, and Taiwan. It is estimated that about 1 000 Japanese longline and pole-and-line vessels are likely to utilize Micronesian ports for their fishing operations.

There is very little information on the current availability and abundance of baitfish in the Trust Territory region. Hida (1971) published the results of a research vessel survey of bait distribution and abundance in the Trust Territory. Sardines (Herklotsichthys sp.) and possibly Sardinella sp., were found in large concentrations on Jaluit and Majuro atolls in the Marshalls. To the south and west of Truk, the islands surveyed showed no substantial amounts of bait except round herring (Spratelloides delicatulus). Hawaiian fishermen claim that round herring are weak bait and do not survive well in the baitwells. Other bait species found by Hida included goatfish, mostly Mulloidichthys samoensis, jack (Caranx spp.), cardinalfish (Apogonidae), bananafish (Caesionidae), silverside (Atherinidae), damselfish (Pomacentridae), and anchovy (Stolephorus indicus). Wilson (1971) surveyed Truk lagoon for bait and found that, among those species that could be used for bait, were snapper (Gymnocaesio argenteus), cardinalfish (Rhabdamia cypselurus), sardine (H. melaneura), round herring (S. delicatulus and S. gracilis), silversides (Allanetta ovalaua and Pranesus pinguis), and damselfish (Pomacentrus pavo). Also, in Majuro and Jaluit in the Marshalls ANELA found good concentrations of both silverside (P. pinguis) and sardine (H. punctatus) (Uchida and Sumida, 1973). At Majuro ANELA caught 205 buckets in five sets or 41 buckets per set. Baiting at Jaluit produced 189 buckets in two sets or 94.5 buckets per set.

The annual catches from the Palau skipjack tuna fishery varied between 2 942 and 8 441 t in 1966-73 (data for 1971 incomplete)and averaged 4 800 t (Table 2). Table 21 gives the monthly catches for 1966-71 whereas Figure 5 shows the average monthly catches, which ranged from 184 t in March to 821 t in July (Congress of Micronesia, 1972). In 1966-71, the number of vessels employed in the fishery never exceeded 12. Skipjack tuna sampled at Malakal Harbor by NMFS observers in 1965-67 ranged between 48 and 62 cm (Uchida, 1970). Usually, the average size tended to increase in October-January.

Recent data on fishing in the Marshall Islands are sparse. In February and again in April-May 1972, ANELA conducted fishing trials around Majuro, Arno, and Jaluit atolls (Uchida and Sumida, 1973). In February, there were several days of good fishing and ANELA landed 20.0 t of skipjack tuna and 1.2 t of yellowfin tuna. Catch per day reached 3.5 t of tuna. In April, however, ANELA found that fishing conditions had deteriorated considerably. Bird flocks were usually smaller and only 3 of the 10 schools pursued and chummed were successfully fished. ANELA caught 2.0 t of skipjack tuna and 0.6 t of yellowfin tuna. Catch per day, which reached 0.6 t, was only one sixth of the average catch per day in February.

In a move to put qualified Micronesian pole-and-line fishermen into tuna vessels they can own and operate themselves, the Marine Resources Division of the Trust Territory has designed a new steel livebait vessel which is destined to replace the wooden-hulled Okinawan-Japanese types now in use (Anon., 1974). The unique feature of this new vessel is that it was literally designed around the baitwells. The design provides for a vessel with a cruising radius of about 1 500 n mi (2 800 km) at speeds up to 9 kn. Carrying a crew of 14, the vessel will have a carrying capacity of about 29 tons in insulated holds. Unique to pole-and-line fishing boats, the new vessel will have doors cut into the hull below the waterline to allow live bait to enter the baitwells without being handled with nets or buckets during transfer.

4. INDIAN OCEAN

Accurate data on the production of skipjack tuna from the Indian Ocean are lacking. According to Shomura et al. (1967), there is every indication that the skipjack tuna resource is underutilized. Sivasubramaniam (1972) estimated that 41 000 to 45 000 t of skipjack tuna

are taken annually from the Indian Ocean, but Kikawa et al. (1969) estimated that this ocean may be capable of yielding about 360 000 t of skipjack tuna per annum. Thus, it is highly conceivable that there is a large resource of skipjack tuna still to be harvested in the Indian Ocean.

According to Jones and Silas (1963), pole-and-line fishing is the most effective method for catching skipjack tuna in the Indian Ocean and is practised around Minicoy Island in the Laccadive Islands, around several islands in the Maldives, and in Sri Lanka (Ceylon). Because of similarities in the method of fishing for skipjack tuna among the fishermen in the Laccadives, Maldives, and Sri Lanka, the fisheries in these areas will be discussed together (Figure 6).

4.1 Laccadive and Maldive Islands and Sri Lanka (Ceylon)

The Laccadive Islands consist of a group of 14 islands and coral reefs in the Arabian Sea, about 200 n mi (370 km) off the southwest coast of India. The islands consist of two main groups: the north group, called the Amindivi Islands; and the south group or the Laccadive Islands proper. The Maldive Islands consist of 13 clusters of coral atolls in the Indian Ocean about 400 n mi (740 km) southwest of Sri Lanka, and Sri Lanka is situated in the Indian Ocean just off the extreme southeast of India. It is connected to the mainland of India by Adam's Bridge, a chain of shoals which divides Palk Strait on the north from the Gulf of Mannar on the south.

Minicoy Island in the Indian Ocean, which lies between the Laccadive and Maldive Islands, is the most important skipjack tuna fishing centre in the Indian Ocean (Jones and Kumaran, 1959). A review of the fishery is from Jones and Kumaran (1959). There is scarcely any difference between the Minicoy fishery and that operating in the Maldives (Jonklaas, 1967), and therefore the following description applies to the fisheries operating in both areas.

The skipjack tuna pole-and-line fishery of Minicoy, on which the economy of the island depends, is seasonal and extends from September to April with the bulk of the catch occurring in December-March. At the start of the skipjack tuna fishing season, the large fishing boats, which are kept covered onshore in the offseason, are launched. Constructed usually of coconut planks fastened by copper nails, they are about 12.5 m long and 3 m wide. There are three to four baitwells with two to three holes on the bottom of each to permit a free flow of water from below. Usually sails and oars are used to propel the craft.

A variety of small fishes found in the lagoon are used as baitfishes (Jones, 1958). The most common ones are pomacentrids, Daya jerdoni, Chromis caeruleus, and Pomacentrus spp. Other important baitfishes are the caesiodids, labrids, atherinids, and apogonids. They are caught with a liftnet. To attract them over the submerged net, crushed crabs and tuna entrails and flesh are scattered in the water. Attracted by the presence of food, the baitfishes gather and feed over the net, which is then quickly raised.

Usually 20-30 people constitute the crew. Fishing grounds are seldom more than 9 n mi (16 km) from the island. The captain is the bait chummer. During fishing 4 or 5 fishermen line up on each side of the vessel and flip the skipjack tuna on board. Fishing usually lasts 10-30 minutes and a fishing trip only 1 day. After the day's catch is unloaded, the skipjack tuna is processed by the womenfolk into smoked and cured fishsticks, locally called "mas min", and exported.

Hiebert and Alverson (1971) recognized several factors that limit extensive development of the Maldivian fisheries. Of primary importance is the availability of live bait (on some islands where it is unobtainable, pole and line are used with a plant lure). Also, because of difficulty in navigating from very deep to shallow water, the fishing vessels have only limited access to distant-water fishing grounds.

A small amount of skipjack tuna are also taken by trolling in the Indian Ocean. According to Jonklaas (1967), some skipjack tuna are taken by trolling gear in the Maldives. Sivasubramaniam (1965) reported that in Sri Lanka, in addition to pole and line, skipjack tuna are caught by troll gear and gillnet (Figure 7). A troll fishery for tuna also exists off the Tinnevelly coast in the Gulf of Mannar (Silas, 1967). However, in this troll fishery, the bulk of the catch consists of kawakawa, longtail tuna (Thunnus tonggol), yellowfin tuna, sailfish (Istiophorus platypterus), and seerfish (Scomberomorus commersoni). Skipjack tuna appeared only rarely in the catch.

In Sri Lanka, pole-and-line fishing has been practised since 1919 (Sivasubramaniam, 1965). Equipment and methods of operation are similar to those of fishermen in Minicoy and the Maldives, where this method has been in operation since 1909.

The live bait used in Sri Lanka is "red bait" (Dipterygonotus leucogrammicus), which congregates over large rocks at depths of 9–18 m. A special dipnet is used to catch the bait. An average day's catch of skipjack tuna and other tunas by a mechanized pole-and-line boat is usually about 0.2 t. Fishing is best off the southwest coast of Sri Lanka in November–March and off the east coast in July–September. Sivasubramaniam (1965) attributed large variations in annual landings of skipjack tuna in Sri Lanka to the annual variations in the spawning stock and availability of live bait.

Table 22 gives the production of skipjack tuna from the Indian Ocean for 1965–72 (FAO, 1973). It is obvious that skipjack tuna from the Maldive Islands predominated but it should be pointed out that production figures from the Maldives were estimated. Jonklaas (1967) stated that it was impossible to obtain any statistical data in such a vast and relatively underdeveloped archipelago. Not even reasonably accurate statistics of annual catches could be obtained, primarily because of the lack of communication and systematic recording of catch data by trained observers; but as a rule, Jonklaas estimated scombroid fishes, primarily skipjack tuna, constituted 90 percent of the fishes caught in the Maldives. Sivasubramaniam (1972) estimated that the Maldivian skipjack tuna fishery produced the largest percentage of the catch followed by the fishery based in Sri Lanka. The Minicoy fishery probably contributed about 1 000 t. Monthly data on fishing effort (days fished) and catches of skipjack tuna, yellowfin tuna, kawakawa, and frigate mackerel are given in Table 23 for 1965 for the fishery operating in the Maldive Islands.

Concerning fishery development in the Indian Ocean, the Japanese, as they have done in the southwestern Pacific, have taken the initiative in attempting to establish fishing bases. Cooperating with the Sri Lanka Government's programme to develop its fisheries, a Japanese firm sent two 250-GT pole-and-line fishing vessels to conduct exploratory skipjack tuna fishing (U.S. NMFS, 1973). The Japanese vessels started fishing in March 1973 in the Indian Ocean from a base at Galle in southwestern Sri Lanka (U.S. NMFS, 1973c). Exploratory fishing will be carried on for 1–1½ years under a permit granted by the Sri Lanka Government. Also, under the agreement, five or six natives and Government officials of Sri Lanka are scheduled to board each of the two Japanese vessels for training. If fishing, baitfish purchases, and labour costs are favourable, the Japanese firm hopes to organize a joint skipjack tuna fishing venture with interests in Sri Lanka.

In the Maldives, two Japanese firms have begun purchasing skipjack tuna (U.S. NMFS, 1972m). It was originally intended that purchases would be about 635 t per month but poor catches have reduced purchases to about 90 t per month. The Japanese firms negotiated a contract with the Maldivian Government to purchase skipjack tuna over the next 6 years.

4.2 Madagascar

Madagascar is an island in the Indian Ocean situated 240 n mi (445 km) off the east coast of Africa.

Fourmanoir (1957, 1960) and Gross (1967) stated that schools of skipjack and yellowfin tuna were frequently reported off the west and northwest coasts of Madagascar, particularly in January-April, i.e., during the warm seasons. Occurrence was reportedly very good even at other times of the year. Marcille (1972) confirmed that good concentrations of skipjack, sometimes associated with yellowfin tuna, are encountered off the northwestern shelf of Madagascar, around the various islands in the Mozambique Channel, as well as further north near the Providence and Amirantes Islands, and Seychelles Bank.

The Japanese started experimental skipjack tuna fishing off Madagascar in February 1972. A Japanese firm, after conducting a feasibility study at Seychelles Islands, has three 190-ton vessels working that area (U.S. NMFS, 1972, 1972e). At the same period, a French firm started exploratory skipjack tuna fishing in the same area. The performances achieved by the Japanese and French vessels are analysed by Marcille and Veillon (1972).

The Japanese pole-and-line boats (34 m, 200 t) concentrated their operations around Farquhar and Aldabra Islands in February-March and then in April-May moved progressively toward the Comoro Islands; from July-November most fishing took place off the northwest coast of Madagascar and in December-January between the islands of Aldabra and Providence; good occurrence of skipjack was also found in the vicinity of the Seychelles Islands where several visits were made at various periods of the year. The French survey arrived at similar conclusions regarding skipjack occurrence. It visited also the waters along the African shelf where little fish was found. In twelve months the three Japanese baitboats caught 4 003 t (3 768 of skipjack; 210 of yellowfin tuna); average daily catch per boat was 5.4 tons; seasonal variations in availability were limited to a slight decrease from July to October. Most of the schools were encountered in waters warmer than 27.5°C. Catches mainly consisted of two length groups (modes at 52 and 67 cm). In general, schools were small and highly mobile. From these observations, combined with the existence of clear waters and deep thermocline, it can be assumed that purse seining would be difficult. This assumption has been confirmed by experimental fishing conducted at a later stage by a French purse seiner (FAO, 1974).

Bait availability proved to be good. Japanese vessels used to catch the bait during the night in bays along the northwest coast of Madagascar at depths between 25 and 35 m. Main species caught were anchovy (Stolephorus indicus), jacks (Decapterus dayi and Selar crumenophthalmus), and sardine (Sardinella sirm). In average, 400-600 kg of fish attracted by light were caught by night with a blanket net. The French boat obtained slightly higher yield (500-700 kg/night) using a small purse seine. Bait resources are also abundant all the year round in the Seychelles Islands. Main species are Rastrelliger kanagurta and Coesio coerulaureus, available in bays.

Based on these fairly satisfactory results the Japanese firm decided to develop its activities. Five baitboats were scheduled to be in operation in April 1973 (Marcille and Veillon, 1973). The attention of other fishing firms, mainly Japanese and French, seeking joint ventures was also attracted. Two Japanese firms were scheduled to form a joint skipjack tuna fishing venture with local interest in November 1974 (U.S. NMFS, 1973d). In 1974, about 10 boats were operating and expected to land about 10 000 t (80-90 percent of skipjack) for that year (FAO, 1974).

TABLE 1. Annual catches (in metric tons) for various established fisheries for skipjack tuna in the Pacific Ocean

Year	Eastern Pacific[1]	Japan[2]	Hawaiian Islands[3]	Ryukyu Islands[4]	Philippine Island[5]
1900	-	-	191	-	-
1903	-	-	345	-	-
1917	190	82,795	-	-	-
1918	1,372	70,091	-	-	-
1919	3,128	64,395	-	-	-
1920	3,609	88,195	-	-	-
1921	517	81,592	-	6,702	-
1922	5,381	65,280	-	6,621	-
1923	5,200	67,784	-	6,423	-
1924	1,715	68,275	-	5,533	-
1925	6,457	69,536	-	4,854	-
1926	9,523	68,767	-	5,034	-
1927	15,335	85,701	-	3,890	-
1928	7,174	76,987	2,007	4,652	-
1929	12,246	72,135	1,514	3,288	-
1930	9,292	68,789	2,829	3,735	-
1931	7,488	80,343	2,777	2,594	-
1932	9,814	67,143	1,434	3,201	-
1933	7,569	77,305	2,522	3,110	-
1934	6,727	84,915	3,594	3,939	-
1935	7,801	72,881	2,210	3,288	-
1936	12,250	101,032	2,523	3,906	-
1937	21,366	105,907	5,800	3,194	-
1938	10,276	120,813	4,410	3,234	-
1939	13,663	100,518	3,903	3,304	-
1940	26,118	116,349	6,087	4,246	-
1941	11,692	91,629	1,656	4,194	-
1942	17,685	79,715	4	3,294	-
1943	13,349	51,691	-	2,318	-
1944	14,127	39,642	-	-	-
1945	15,438	19,653	1,772	-	-
1946	19,256	41,447	2,554	1,302	-
1947	24,259	48,732	2,536	2,945	-
1948	27,885	40,716	3,803	2,846	-
1949	36,749	46,471	4,488	3,419	-
1950	58,634	84,626	4,314	3,495	-
1951	54,948	104,309	5,863	2,606	-
1952	41,179	85,924	3,308	3,714	-
1953	60,626	72,690	5,470	2,620	-
1954	78,805	99,191	6,360	5,143	-
1955	58,061	99,626	4,397	3,235	-
1956	68,176	97,988	5,050	4,111	-
1957	58,197	97,418	2,781	4,056	-
1958	74,799	147,433	3,100	7,064	-
1959	80,559	166,707	5,631	10,957	-
1960	50,123	78,608	3,338	4,406	-
1961	64,910	144,327	4,942	5,922	-
1962	73,211	170,284	4,271	7,284	-
1963	93,033	112,887	3,674	5,514	-
1964	56,791	166,763	4,093	5,043	-
1965	84,324	136,067	7,329	3,800	-
1966	60,057	191,600	4,257	3,521	-
1967	122,381	154,200	3,647	5,136	500
1968	70,444	125,900	4,227	6,000	2,400
1969	58,605	138,800	2,705	3,400	600
1970	50,077	151,300	3,334	9,700	200
1971	103,330	99,100	6,051	21,700	700
1972	31,933	160,700	4,952	-	3,500
1973	42,457	201,000	4,875	-	2,500

[1]Data for 1917-66 are from Rothschild and Uchida (1968); data for 1967-73 are from Inter-American Tropical Tuna Commission (1974).

[2]Data for 1917-65 are from Rothschild and Uchida (1968); data for 1966-72 are from FAO (1973); figure for 1973 is from Kearney (p.4)

[3]Data for 1900-66 are from Rothschild and Uchida (1968); data for 1967-73 are from catch records of the Hawaii Division of Fish and Game.

[4]Data for 1921-67 are from Isa (1972); data for 1968-71 are from FAO (1972).

[5]Data for 1967-71 are from FAO (1972); data for 1972-73 are from Kearney (p.4).

TABLE 2. Annual catches (in metric tons) in newly developed or developing fisheries for skipjack tuna in the Pacific Ocean

Year	French Polynesia[1]	Indonesia[2]	New Hebrides[2]	Palau[3]	Papua New Guinea[4]	Solomon Islands[5]
1953	261	--	--	--	--	--
1954	324	--	--	--	--	--
1955	279	--	--	--	--	--
1956	371	--	--	--	--	--
1957	252	--	--	--	--	--
1958	181	--	--	--	--	--
1959	268	--	--	--	--	--
1960	320	--	--	--	--	--
1961	286	--	--	--	--	--
1962	385	--	--	--	--	--
1963	519	--	--	--	--	--
1964	401	--	2,900	--	--	--
1965	515	--	3,400	--	--	--
1966	731	--	5,700	2,942	--	--
1967	519	11,716	4,800	3,404	--	--
1968	--	12,907	6,700	5,212	--	--
1969	--	13,413	6,800	6,186	--	--
1970	--	13,642	6,800	8,441	2,430	--
1971	--	13,350	6,800	1,717	17,002	4,707
1972	--	13,317	6,800	[6]5,000	13,124	7,643
1973	--	[6]13,000	[3]6,800	[6]6,000	[6]28,000	6,500

[1]Data for 1953-55 are from Van Pel and Devambez (1957); data for 1956-67 are from Brun and Klawe (1968). Landings are for eviscerated fish. FAO (1972) estimates landings to be about 1,500 MT per year in 1965-71.

[2]Data are from Kearney (p. 4). Figures for New Hebrides may be higher than actual catches.

[3]Data are from Congress of Micronesia (1972). Catches for November-December 1971 not available at time of publication.

[4]Data for 1970-71 are from Kearney (1973); data for 1972-73 are from Kearney (1974); catches include small amounts of other tunas.

[5]Data for 1971-72 are from Kearney (personal communication); data for 1973 are from U.S. NMFS (1974).

[6]Estimated.

TABLE 3. Monthly landings of skipjack tuna, Katsuwonus pelamis, at the Papeete Market (in kg) (from Brun and Klawe, 1968)

Year	Month												Total
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1954		41,807	23,952	6,903	31,031	31,445	15,547	8,746	18,940	35,098	39,696	29,791	282,956
1955	34,000	37,567	34.835	32,449	51,564	19,538	11,311	3,467	6,294	5,286	9,059	33,492	278,862
1956	47,412	44,326	46,527	40,417	36,504	14,262	14,660	8,632	8,589	3,640	36,245	69,473	370,687
1957	50,408	35,684	32,357	22,495	29,149	21,120	7,788	5,185	4,364	13,689	12,901	17,228	252,368
1958	14,897	19,392	14,567	13,946	32,857	16,474	10,395	7,340	12,347	11,611	13,466	13,557	180,849
1959	14,050	14,020	9,889	16,956	36,729	36,274	19,737	13,339	8,512	22,973	22,953	52,093	267,525
1960	39,881	41,873	36,131	41,114	33,486	29,659	15,512	5,407	3,494	9,775	23,149	40,385	319,866
1961	41,419	35,034	32,480	29,370	33,145	22,161	10,579	9,228	8,423	16,290	18,822	29,064	286,015
1962	30,344	30,056	39,451	41,870	34,589	25,236	16,290	7,767	24,069	44,290	38,678	52,512	385,152
1963	78,223	41,742	40,993	45,540	61,327	40,677	26,361	21,789	23,711	27,747	48,314	62,917	519,341
1964	41,989	40,933	43,508	31,374	41,409	24,840	12,588	15,109	21,122	33,555	46,456	47,864	400,747
1965	38,183	34,535	32,410	41,479	62,915	57,759	26,103	28,443	23,831	42,572	49,126	77,892	515,248
1966	70,289	48,881	41,198	53,849	63,616	78,799	51,443	48,984	75,488	75,792	63,792	58,759	730,860
1967	51,926	79,328	56,603	44,950	62,654	35,198	13,903	6,030	12,091	41,105	46,033	69,172	518,993
1968	58,291												

TABLE 4. Monthly landings of yellowfin tuna, Thunnus albacares, at the Papeete Market (in kg) (from Brun and Klawe, 1968)

Year	Month											Total
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1954		11,468	7,206	8,474	10,398	9,514	3,465	1,913	2,631	3,846	9,913	6,491	75,319
1955	7,063	14,775	4,394	7,777	7,974	4,223	3,137	2,410	2,160	2,440	1,132	4,073	61,558
1956	12,303	7,269	8,907	2,425	2,368	1,754	1,285	867	112	654	1,170	1,454	40,568
1957	3,296	5,777	5,690	7,162	6,496	2,110	1,756	447	342	2,539	4,273	3,954	43,842
1958	8,959	23,987	13,392	4,409	7,706	5,273	2,389	1,877	1,172	1,009	2,588	5,724	78,485
1959	12,805	5,557	8,340	6,016	8,524	3,090	1,986	2,689	1,073	5,389	9,232	10,686	75,387
1960	2,886	1,371	12,395	6,208	7,352	7,820	4,382	3,545	1,063	1,055	1,780	9,948	59,805
1961	19,570	15,422	13,504	18,409	10,258	4,628	3,737	712	1,148	1,737	5,038	14,672	108,835
1962	16,756	20,010	12,132	10,090	13,525	8,051	5,243	2,792	664	1,840	8,788	26,273	126,164
1963	17,170	15,431	18,017	6,080	9,256	5,559	3,795	2,001	2,108	4,655	9,172	13,823	107,067
1964	10,551	8,232	11,389	11,830	11,590	7,040	4,751	3,695	2,017	1,504	5,073	9,906	87,578
1965	5,021	5,475	4,673	2,622	3,967	3,340	3,416	567	743	1,073	3,437	6,758	41,092
1966	7,987	7,933	3,841	2,873	8,478	4,551	2,950	1,828	1,961	2,689	5,820	7,366	58,277
1967	21,270	28,982	26,421	9,364	9,498	8,232	1,567	509	185	2,844	2,204	9,798	120,872
1968	13,180												

TABLE 5. Live-bait skipjack tuna fishery experiments in various French Polynesian Island groups (from Doumenge, 1973)

Boat	Period	Trips	Fish caught								Total		Yield/trip	
			Skipjack tuna						Yellowfin tuna					
			2-3 kg		3-8 kg		8-20 kg							
			No.	kg	No.	kg	No.	kg	No.	kg	No.	kg	No.	kg
Leeward Islands														
Moetu	20-25 Feb. 1972	2	27	54							27	54	13.5	27
	19-30 Mar. 1972	5	970	2,910					62	2,440	1,032	5,350	206.4	1,078
	1-7 July 1972	7	181	543					173	990	354	1,533	50.5	219
	21-24 Aug. 1972	2			270	4,050					270	4,050	135	2,025
	28 Aug.-8 Sept. 1972	4	162	426					3	90	165	516	41	129
Anela	14-20 Dec. 1972	4	635	3,810	396	3,168	37	555	46	257	1,114	7,790	2,785	1,947.5
	14-18 Jan. 1973	2	80	160			731	10,103	6	80	817	10,343	408.5	5,171.5
Tuamotu														
Moetu	24 July-3 Aug. 1972	4	79	237	2	16					81	253	20	55.5
Anela	3-7 Dec. 1972	3	246	663							246	663	82	221
Marquesas														
Anela	19 Feb.-25 Mar. 1973	5			1,735	10,410					1,735	10,410	347	2,082
	27 May-7 Apr. 1973	1	391	1,173	2,110	16,880					2,501	18,053	2,501	18,053

TABLE 6. Results of experimental live-bait fishery in the Windward Islands (from Doumenge, 1973)

Boat	Period	Trips	Fish caught										Total		Yield/trip	
			Skipjack tuna						Yellowfin tuna							
			2-3 kg		3-8 kg		8-20 kg									
			No.	kg	No.	kg	No.	kg	No.	kg			No.	kg	No.	kg
Moetu	15-18 Feb. 1972	1	32	64					24	48			56	112	56	112
	6-11 Mar. 1972	2	34	68			46	690	10	100			90	868	45	434
	13-18 Mar. 1972	1			1	8	127	1,916					128	1,926	128	1,926
	30 Mar.-2 Apr. 1972	1					80	1,200					80	1,200	80	1,200
	4-8 Apr. 1972	2	50	150					36	360			86	510	43	255
	10-13 Apr. 1972	3	108	216			2	30	100	1,200			210	1,446	70	482
	17-22 Apr. 1972	3	98	196	2	16			17	85			117	297	39	99
	25-29 Apr. 1972	2					15	180					15	180	7.5	90
	9-19 May 1972	5	229	458			87	870	70	420			386	1,748	77.2	349.6
	23-28 May 1972	4			13	91	42	425	2	82			57	598	20.5	149.5
	29 May-2 June 1972	2	22	44					19	95			41	139	20.5	69.5
	5-10 June 1972	2			87	435							87	435	43.5	217.5
	Total	28	573	1,196	103	550	399	5,313	278	2,390			1,353	9,449	48.5	337.5
Anela	10-13 Dec. 1972	3	907	2,721	204	1,020	121	1,573	79	237			1,311	5,551	437	1,850
	7-11 Jan. 1973	3	72	37			853	11,089					925	11,126	308.3	3,708.6
	12 Jan. 1973	1			253	3,102							253	3,102	253	3,102
	25-26 Jan. 1973	2					500	8,068					500	8,068	250	4,034
	28-30 Jan. 1973	2					1,606	21,722					1,606	21,722	803	10,861
	31 Jan.-2 Feb. 1973	2	20	40			982	12,766	2	4			1,004	12,810	502	6,405
	4-7 Feb. 1973	3					1,300	16,900					1,300	16,900	433.3	5,633.3
	8-9 Feb. 1973	1					311	4,043					311	4,043	311	4,043
	10-15 Feb. 1973	2					1,418	18,434					1,418	18,434	709	9,217
	Total	19	999	2,798	457	4,122	7,091	94,595	81	241			8,628	101,756	449	5,355.5
Redondo	27 Mar.-7 Apr. 1973	5	161	644			50	750	1,200	3,600			1,411	4,994	282.2	998.8
	Grand total	52	1,733	6,638	560	4,672	7,540	100,658	1,559	6,231			13,392	116,199		

TABLE 7. The species and amount of baitfish caught day and night baiting in Pago Pago Harbor and Apia Harbor by the RV Charles H. Gilbert (from Hida, 1970)

Baiting locality	Time of day	Sets	Amount of bait caught	Species
		Number	Buckets	
Pago Pago Harbor	Night	8	54	Mackerel, Rastrelliger kanagurta
			22	Sardines, Sardinella melaneura and Herklotsichthys punctatus
			4	Bigeye scad, Trachurops crumenophthalmus
	Day	31	88	Sardines, S. melaneura and H. punctatus
Apia Harbor	Day	5	13	Silverside, Pranesus pinguis

TABLE 8. Baiting effort (sets), total catch by species and all species combined, and catch per set at night baiting stations at American Samoa, August 1970-June 1973

Month-year	No. of sets	Total catch	Catch per set	Stolephorus sp.		Sardinella spp.		Herklotsichthys punctatus		Others	
				Amount caught		Amount caught		Amount caught		Amount caught	
	No.	Bkt.	Bkt.	Bkt.	Percent	Bkt.	Percent	Bkt.	Percent	Bkt.	Percent
Aug.-Dec. 1970	67	202	3.0	90	44.6	32	15.8	64	31.7	16	7.9
Jan.-Dec. 1971	133	337	2.5	72	21.4	43	12.8	68	20.2	154	45.7
Jan.-Dec. 1972	49	149	3.0	23	15.4	3	2.0	31	20.8	92	61.7
Jan.-Jun. 1973	58	119	2.0	7	5.9	76	63.9	23	19.3	13	10.9

Data for August 1970-June 1972 are from Swerdloff (1974); data for July 1972-June 1973 are from Sesepasara (1973).

TABLE 9. Noon positions, dates and number and kinds of schools sighted around the Samoa Islands during cruise 117 of the RV Charles H. Gilbert (from Hida, 1970)

Noon Position		Date	Number of Schools Sighted[1]						
Lat. (S.)	Long. (W.)	1970	SJ	YF	KK	Mixed YF, SJ	UN	Mixed KK, DO, SK	Total
12°00'	169°15'	2/8	-	-	-	-	4	-	4
South of Pago Pago		2/11	-	-	-	-	5	-	5
16°55'	170°45'	2/12	2	1	-	-	4	-	7
16°03'	170°13'	2/13	4	-	-	-	2	-	6
14°33'	170°23'	2/15	2	-	-	-	2	-	4
14°30'	169°22'	2/16	-	1	-	1	3	-	5
13°37'	169°24'	2/17	-	-	-	-	1	-	1
14°09'	171°00'	2/23	-	-	1	-	2	-	3
14°27'	171°45'	2/25	1	-	-	-	-	-	1
13°49'	173°15'	2/26	-	3	-	2	4	-	9
13°50'	172°08'	2/27	-	-	2	-	3	-	5
14°12'	172°12'	3/1	1	1	1	1	1	-	5
14°45'	171°02'	3/2	1	-	-	-	5	-	6
14°19'	170°36'	3/5	-	-	-	-	3	-	3
14°18'	170°35'	3/6	-	-	-	-	4	-	4
14°19'	170°39'	3/10	-	-	1	-	1	-	2
14°17'	170°53'	3/11	-	-	1	-	-	1	2
14°51'	170°30'	3/14	2	-	-	-	1	-	3
14°11'	170°14'	3/18	-	2	-	-	4	-	6
14°02'	169°22'	3/19	-	-	-	2	4	-	6
14°39'	168°36'	3/20	4	-	-	1	2	-	7
14°38'	170°14'	3/21	3	-	-	-	5	-	8
14°25'	170°47'	3/23	3	-	-	-	4	-	7
15°42'	170°45'	3/24	-	-	-	-	2	-	2
14°23'	170°35'	3/25	-	-	-	-	1	-	1
14°15'	170°56'	3/26	2	1	1	1	4	-	9
13°46'	171°45'	3/27	-	-	-	-	2	-	2
13°42'	173°08'	3/28	1	1	-	-	3	-	5
14°15'	172°29'	3/29	-	-	1	-	5	-	6
13°44'	171°50'	3/31	-	-	2	2	1	-	5
15°03'	171°16'	4/1	2	1	-	-	2	-	5
Total			28	11	10	10	84	1	144

[1] SJ = skipjack; YF = yellowfin; KK = kawakawa; UN = unidentified; DO = dolphin; SK = shark.

TABLE 10. Information on large tuna schools seen in the vicinity of the Samoa Islands during cruise 117 of the RV Charles H. Gilbert (from Hida, 1970)

Position		Date	Species	Fish Size	Type of
Lat. (S)	Long. (W)	1970	Common names of tuna	pounds	School[1]/
14°30'	169°21'	2/16	Yellowfin	20-50	Boiler
13°25'	172°45'	2/26	Yellowfin	30-40	Boiler
14°09'	172°11'	3/1	Yellowfin-Skipjack	7-16	Boiler
14°12'	169°35'	3/19	Yellowfin-Skipjack	5	Breezer
13°30'	168°41'	3/19	Skipjack Yellowfin	11 60	Breezer
14°39'	168°25'	3/20	Skipjack	10	Boiler
14°37'	168°25'	3/20	Skipjack	10	Boiler
14°45'	168°51'	3/20	Skipjack	6	Boiler
14°26'	170°42'	3/23	Skipjack	8	Breezer
14°27'	170°46'	3/23	Skipjack	7-8	Breezer
13°54'	171°21'	3/26	Skipjack	5	Breezer
14°12'	172°04'	3/31	Skipjack Yellowfin	6 9	Jumper

[1]/ See Scott (1969) for school terminology.

TABLE 11. Catches of skipjack tuna and other tunas caught in Australian waters, 1960-61 to 1971-72

Fiscal year	Catch (MT)	
	Tuna[1]	Skipjack tuna
1960-61	4,429	--
1961-62	4,814	--
1962-63	4,989	48
1963-64	8,134	34
1964-65	7,184	2
1965-66	8,054	1
1966-67	5,649	2
1967-68	6,792	4
1968-69	8,916	35
1969-70	8,450	1
1970-71	6,802	42[2]
1971-72	10,125	105[2]

[1]Catches from 1960-61 to 1969-70 include catches of skipjack tuna not reported separately by several states.

[2]Catches of skipjack tuna in 1970-71 and 1971-72 are reported separately from other tunas.

TABLE 12. Number and percentages of schools, by species, sighted in Fijian waters in 1972

Species	Schools sighted	
	Number	Percent
Skipjack tuna	247	37.8
Yellowfin tuna	53	8.1
Skipjack-yellowfin mixed	44	6.7
Kawakawa	40	6.1
Skipjack-kawakawa mixed	8	1.2
Tuna-pelagic species mixed	28	4.3
Mahimahi (Coryphaena hippurus)	18	2.8
Miscellaneous species	18	2.8
Unidentified	197	30.2
Total sightings	653	

TABLE 13. Summary of joint-venture operations in Indonesia

Month and year	Area of operation	Size of fleet	Remarks
Nov. 1969 to Mar. 1971[1]	Sorong, West Irian.	Five 110-ton catcher vessels, four 10-ton bait catchers, and one 700-ton freezer mother ship.	Results of fishing not satisfactory.
Apr.-Sept. 1971[2]	In Molucca Sea off Halmahera Island; vessels based in Ternate.	Five 110-ton catcher vessels two 400-ton carriers.	Joint venture, called East Indonesian Fisheries Company formed. Plans call for fleet of 10 vessels. Catch target for first year is 4,000 MT. Vessel crew half Japanese and half Indonesian at present; to be all Indonesian in future.
Aug. 1971[3]	Butung Island in Banda Sea.	Three catcher vessels and one mother ship.	No information on results of survey.
Sept. 1971[4]	Pandiang, Sumatra Island with fishing in Sunda Strait.	Three or four catcher vessels.	Operations terminated in March 1972; probably because of poor fishing.
Sept. 1971[5]	Kendari, Celebes Island.	Five 39-ton catcher vessels and one 1,000-ton mother ship.	Joint venture formed. Landings reached 600 tons. Catch was 2-3 tons per vessel per day. Bait available in sufficient amounts.
Dec. 1971 to July 1972[1]	West coast of Sumatra Island in the Indian Ocean.	One 190-ton catcher vessel.	Survey terminated after a few months because of difficulty in obtaining sufficient quantities of live bait and because of poor weather conditions.
May 1972 to Dec. 1972[1]	Kotobaru on Laut Island; test fishing in Makassar Strait and in Flores Sea.	One 190-ton catcher vessel.	Results were disappointing, but conclusion was that a brief test fishing by a single vessel was inadequate.

Source of information:

[1]Katsuo-Maguro Nenkan, 1973
[2]U.S. NMFS, 1971, 1971b, 1971i, 1972f
[3]U.S. NMFS, 1971e
[4]U.S. NMFS, 1971f, 1972b
[5]U.S. NMFS, 1972b, 1972d

TABLE 14. Summary of joint-venture operations in Papua New Guinea (from Pownall, 1972)

Joint venture base location	Fleet	Area of operation	Future plans
Kavieng on northern tip of New Ireland; also a tuna smoke-drying plant on Nago Island	Operates two mother ships (1,000 and 500 GT), a 150-ton Japanese steel catcher boat with automatic fishing poles, and nine chartered Okinawan 39-ton, wood, pole-and-line fishing boats.	Bismarck Sea	[No information]
Rabaul in New Britain	Operates two mother ships and nine chartered Okinawan catcher boats.	Bismarck Sea	Hopes to increase fleet to 3 mother ships and 15 catcher boats; expects to catch 15,000 tons of skipjack tuna per year; plans to build a cold storage and a smoking plant. Within 5 years, they expect to be operating five boats under Papua New Guinea flag. Fishery training expected for 500 Papua New Guinean fishermen.
Madang	Operates two mother ships (1,000 tons), eight chartered Okinawan, and one 192-ton Japanese catcher boats.	[No information]	Catches were disappointing; all vessels in fleet except one large Japanese catcher boat returned to Japan.
Still on survey	Operates one mother ship; three chartered Okinawan catcher boats, and the 400-ton pole-and-line vessel, Redondo.	Bismarck Sea	[No information]

TABLE 15. Distribution by area of the total catch and average weight of skipjack tuna in 1971 (from Kearney, 1973)

1971	Northeastern Bismarck Sea		Eastern Bismarck Sea		Southwestern Bismarck Sea	
	Total catch	Average weight of skipjack tuna	Total catch	Average weight of skipjack tuna	Total catch	Average weight of skipjack tuna
	Tons	Kg	Tons	Kg	Tons	Kg
January	447.6	3.9	470.1	-	0	-
February	625.3	3.8	366.6	-	0	-
March	477.3	3.9	569.4	-	414.9	5.0
April	367.8	3.8	645.8	-	498.1	4.8
May	649.4	3.7	788.4	4.0	446.7	4.7
June	224.3	3.3	1078.9	-	736.3	5.1
July	87.7	3.5	1348.3	4.2	516.5	4.9
August	353.3	3.3	1257.0	3.9	416.5	4.9
September	534.9	3.4	818.9	3.8	135.8	4.7
October	538.1	3.8	520.2	4.6	16.3	5.0
November	412.8	3.40	462.7	4.2	86.9	3.6
December	129.5	3.2	381.6	4.0	188.5	4.5
Total	4,837.1		8,707.9		3,456.5	
Grand total					17,002.5	

TABLE 16. Monthly catches of skipjack, yellowfin, and other tunas in the Papua New Guinea skipjack tuna fishery, 1970-71 (from Kearney, 1973)

Year	Month	Catch (metric ton)				Average catch/day
		Skipjack	Yellowfin	Others	Total	
1970	Jan.	-	-	-	-	-
	Feb.	-	-	-	-	-
	Mar.	279.2	27.8	0.0	307.0	3.743
	Apr.	336.6	11.3	0.1	348.0	4.704
	May	361.8	8.2	0.1	370.1	4.512
	June	438.5	2.5	0.0	441.0	5.444
	July	472.8	7.5	0.0	480.3	6.403
	Aug.	101.4	11.3	0.0	112.7	4.026
	Sept.	-	-	-	-	-
	Oct.	-	-	-	-	-
	Nov.	143.9	0.3	1.0	145.2	4.539
	Dec.	220.3	5.4	0.5	226.2	3.968
Totals:		2,354.5	74.3	1.7	2,430.5	
1971	Jan.	899.7	16.7	1.3	917.7	3.543
	Feb.	969.8	21.3	0.8	991.9	3.493
	Mar.	1,445.0	13.8	0.8	1,461.6	4.402
	Apr.	1,499.1	6.4	6.1	1,511.6	4.270
	May	1,862.2	15.1	7.1	1,884.4	5.510
	June	2,037.9	1.3	0.4	2,039.6	6.433
	July	1,950.6	0.8	1.1	1,952.5	5.515
	Aug.	2,021.9	3.0	1.9	2,026.8	4.231
	Sept.	1,486.0	3.0	0.6	1,489.6	3.547
	Oct.	1,058.3	2.7	2.6	1,064.6	3.775
	Nov.	945.6	15.6	1.3	962.5	2.856
	Dec.	687.6	8.3	3.7	699.6	2.332
Totals:		16,863.7	108.0	27.7	17,002.4	

TABLE 17. Skipjack tuna baitfish used in the Ryukyu Islands (asterisks denote important species) (from Isa, 1972)[1]

Family	Species	Japanese name	Local name
Clupeidae	Sardinella clupeoides	Yamato-mizun	Yamato-mizun
	Sardinella sindensis	Miyako-iwashi	Mizun
	Harengula ovalis	Mizun	Mizun or ashichin
Dorosomatidae	Konosirus punctatus	Konoshiro	Ashichin
Dussumieridae	*Spratelloides japonicus	Kibinago	Sururu
	*Spratelloides delicatulus	Minami-kibinago	Shiiraa
	Spratelloides atrofasciatus	Bakajako	Bakajako
Engraulidae	Stolephorus indicus	Indo-ainoko	Mizusururu
	Stolephorus zollingeri	Taiwan-ainoko	Mizusururu
	*Stolephorus pseudoheterolobus	Mizusururu	Mizusururu
Atherinidae	Allanetta woodwardi	Okinawa-toogoroo	Hadaraa
Carangidae	Decapterus macrosoma	Kusayamoro	Nagaiyuu
	*Trachurops crumenophthalmus	Meaji	Gatsun
Apogonidae	*Archamia fucata	?	Ufumii
	Apogon notatus	Kurohoshi-ishimochi	Ufumii
Pempheridae	Parapriacanthus beryciformis	Kinmemodoki	Gasagasaa
Caesionidae	*Caesio tile	Kumasasa-hanamuro	Ukuu
	*Caesio chrysozonus	Takasago	Saneeraa
Pomacentridae	*Chromis ternatensis	Kaburaya-suzumedai	Hikaagwaa
	Chromis caeruleus	Debasuzumedai	Hikaagwaa
	Abudefduf dickii	Ishigaki-suzumedai	Hikaagwaa

[1]Source: Mr. Nishijima, University of Ryukyu Islands, pers. comm.

TABLE 18. Baitfish used, in metric tons, in the three major localities in the Ryukyu Islands skipjack tuna fishery, 1966 and 1967 (from Isa, 1972)

Baitfish family	Yaeyama		Miyako		Okinawa		Total	
	1966	1967	1966	1967	1966	1967	1966	1967
Apogonidae	34.9	77.5	7.7	10.5	29.5	23.1	71.7	111.1
Caesionidae	16.7	35.4	20.5	1.2	29.9	15.7	67.1	52.3
Dussumieridae	3.3	3.2	6.0	22.7	45.4	19.1	54.7	45.0
Engraulidae	1.5	-	2.1	17.2	15.3	8.2	18.9	25.4
Carangidae	0.4	-	0.9	-	40.1	17.7	41.4	17.7
Clupeidae	0.5	-	-	-	7.3	5.0	7.8	4.8
Pomacentridae	4.0	5.6	0.1	-	-	0.5	4.1	6.1
Dorosomatidae	-	-	-	-	1.0	6.8	1.0	6.8
Others	7.5	-	-	-	-	-	7.5	-
Total	68.8	121.7	37.3	51.6	168.1	96.1	274.2	269.4

TABLE 19. Monthly landings (in metric tons) of skipjack tuna in the Ryukyu Islands, 1959, 1962-63, and 1965-67 (from Isa, 1972)

Month	1959	1962	1963	1965	1966	1967	Monthly average	Percent
January	20.4	6.2	5.5	15.5	23.5	72.1	23.9	0.4
February	21.0	7.1	2.3	15.1	30.1	86.3	26.9	0.4
March	14.5	11.8	3.2	11.8	28.8	23.3	15.6	0.2
April	99.0	89.6	118.0	62.1	128.7	33.6	88.5	1.4
May	643.3	602.0	581.3	469.8	283.1	241.0	470.1	7.6
June	1,766.8	1,518.7	843.9	420.9	466.7	788.6	967.6	15.6
July	3,594.4	2,127.8	1,584.4	1,164.7	1,145.4	1,342.9	1,826.6	29.5
August	2,742.9	1,671.9	1,424.2	933.6	1,011.1	1,397.5	1,530.2	24.7
September	1,650.8	1,017.6	678.9	419.2	200.8	967.6	822.5	13.3
October	1,223.8	139.9	175.0	135.4	179.1	152.8	334.3	5.4
November	69.3	26.2	53.0	68.7	16.7	14.2	41.4	0.7
December	111.5	1.4	43.5	62.4	7.4	15.6	40.3	0.6
Total	11,957.7	7,220.2	5,513.2	3,779.2	3,521.4	5,135.5	6,187.9	100.0

Source: GRI Annual Fisheries Reports for 1959, 1962-63 and 1965-67.

TABLE 20. Skipjack tuna catch in metric tons landed in the former Japanese mandated islands, 1922-41 (from Smith, 1947; Shapiro, 1948)

	Saipan	Yap	Palau	Truk	Ponape	Jaluit
1922	2	-	-	4	4	-
1923	3	1	-	3	-	-
1924	9	2	2	5	<1	-
1925	15	2	9	6	5	-
1926	45	2	42	3	<1	-
1927	28	<1	15	8	2	<1
1928	26	1	131	5	<1	-
1929	25	<1	229	215	<1	-
1930	258	<1	157	913	6	-
1931	564	<1	548	1,097	525	81
1932	1,310	-	1,592	810	534	615
1933	1,762	-	2,144	1,883	927	172
1934	2,516	4	3,779	1,200	1,202	255
1935	1,786	-	5,391	3,002	1,313	230
1936	1,696	-	3,836	5,870	2,696	168
1937	2,697	-	13,775	12,434	4,064	91
1938	2,392	149	3,420	5,295	1,496	7
1939	2,087	36	3,549	7,640	3,708	-
1940	3,379	4	6,047	7,217	1,586	<1
1941	1,295	5	3,301	4,337	2,419	169

TABLE 21. Number of boats fishing, catches of skipjack tuna, and catch per boat, by month, in the Palau skipjack tuna fishery, 1966-71 (from Congress of Micronesia, 1972)

Month	1966			1967			1968		
	Boats	Catch	Catch per boat	Boats	Catch	Catch per boat	Boats	Catch	Catch per boat
	No.	MT	MT	No.	MT	MT	No.	MT	MT
January	—	101.414	—	5	361.103	72.2	10	341.896	34.2
February	—	220.402	—	4	107.918	26.9	9	477.397	53.0
March	—	133.402	—	4	101.678	25.4	8	443.479	55.4
April	—	108.210	—	4	120.516	30.1	6	375.414	62.5
May	—	161.820	—	4	130.399	32.6	6	733.787	122.3
June	—	185.283	—	10	258.949	25.9	11	771.853	70.1
July	—	524.830	—	10	384.659	38.4	11	996.055	90.5
August	—	326.672	—	9	430.843	47.9	9	769.427	85.4
September	—	477.440	—	10	210.327	21.0	9	177.879	19.7
October	8	320.839	40.1	10	205.587	20.6	5	37.497	7.5
November	8	250.227	31.2	10	580.735	58.1	6	84.864	14.1
December	8	130.871	16.3	9	510.787	56.7	4	2.868	0.7
Total	—	2,941.600	—	—	3,403.501	—	—	5,212.416	—
Average	—	245.134	—	7.4	283.625	38.2	7.8	434.368	55.5
	1969			1970			1971		
January	8	72.107	9.0	7	389.421	55.7	6	242.875	40.4
February	9	141.385	15.8	7	274.983	39.2	6	102.734	17.1
March	8	35.330	4.4	6	192.730	32.1	8	199.799	24.9
April	5	58.195	11.6	7	422.949	60.4	7	190.919	27.2
May	5	259.846	51.9	9	1,021.297	113.5	8	466.544	58.3
June	4	623.630	155.9	9	1,642.223	182.4	8	282.685	35.3
July	8	678.585	84.8	9	2,343.803	260.4	12	72.200	6.0
August	9	1,282.252	142.4	9	1,055.522	117.3	12	78.200	6.6
September	9	809.540	89.9	2	95.873	47.9	12	197.877	16.5
October	9	593.678	65.9	5	149.753	29.5	6	31.895	5.3
November	7	702.714	100.4	5	512.560	102.5	—[1]	—	—
December	7	929.011	132.7	6	340.172	56.7	—[1]	—	—
Total	—	6,186.183	—	—	8,441.286	—	—	1,716.832	—
Average	7.3	515.515	70.3	6.75	703.441	104.2	8.5	171.683	20.2

[1]Data unavailable at time of publication.

TABLE 22. Catches of skipjack tuna in the Indian Ocean, 1965-72

Year	Maldive Islands (1,000 MT)	Japan (1,000 MT)	Australia (1,000 MT)
1965	13.1[1]	0.1	--
1966	15.9[1]	0.1	--
1967	17.9[1]	0.2	--
1968	16.3[1]	0.3	--
1969	18.4	0.3	--
1970	20.0[1]	0.1	--
1971	28.9	0.1	0.0
1972	15.0[1]	0.1	0.1

[1]Data estimated or calculated by FAO.

TABLE 23. Catch of tuna (in thousands of fish) and fishing days by month and type of boat in the Maldive Islands, 1965. (a) Skipjack and yellowfin tunas; (b) Large skipjack tuna; (c) Kawakawa and frigate mackerel (from Hiebert and Alverson, 1971)

	Large boat (live-bait fishing)				Small boat (mailing trolling)			
	Days** fishing	(a)	(b)	(c)	Days** fishing	(a)	(b)	(c)
January	18,908	1,156	66	1,083	11,915	49	3	72
February	16,949	933	21	492	12,232	28	1	91
March	15,341	715	3	291	9,262	20	1	32
April	13,322	464	6	166	10,062	14	*	29
May	11,301	553	10	92	11,585	32	1	32
June	14,145	616	4	126	11,994	58	1	51
July	15,067	460	13	74	11,870	22	2	29
August	13,184	452	21	114	10,408	53	2	32
September	11,664	274	40	84	10,190	15	*	25
October	14,444	364	62	294	10,568	22	5	42
November	15,730	333	47	347	10,412	36	1	32
December	17,295	597	76	125	13,667	69	4	50
Total	177,350	6,917	369	3,288	134,165	418	21	517

* less than 500.

** minor discrepancies are due to rounding.

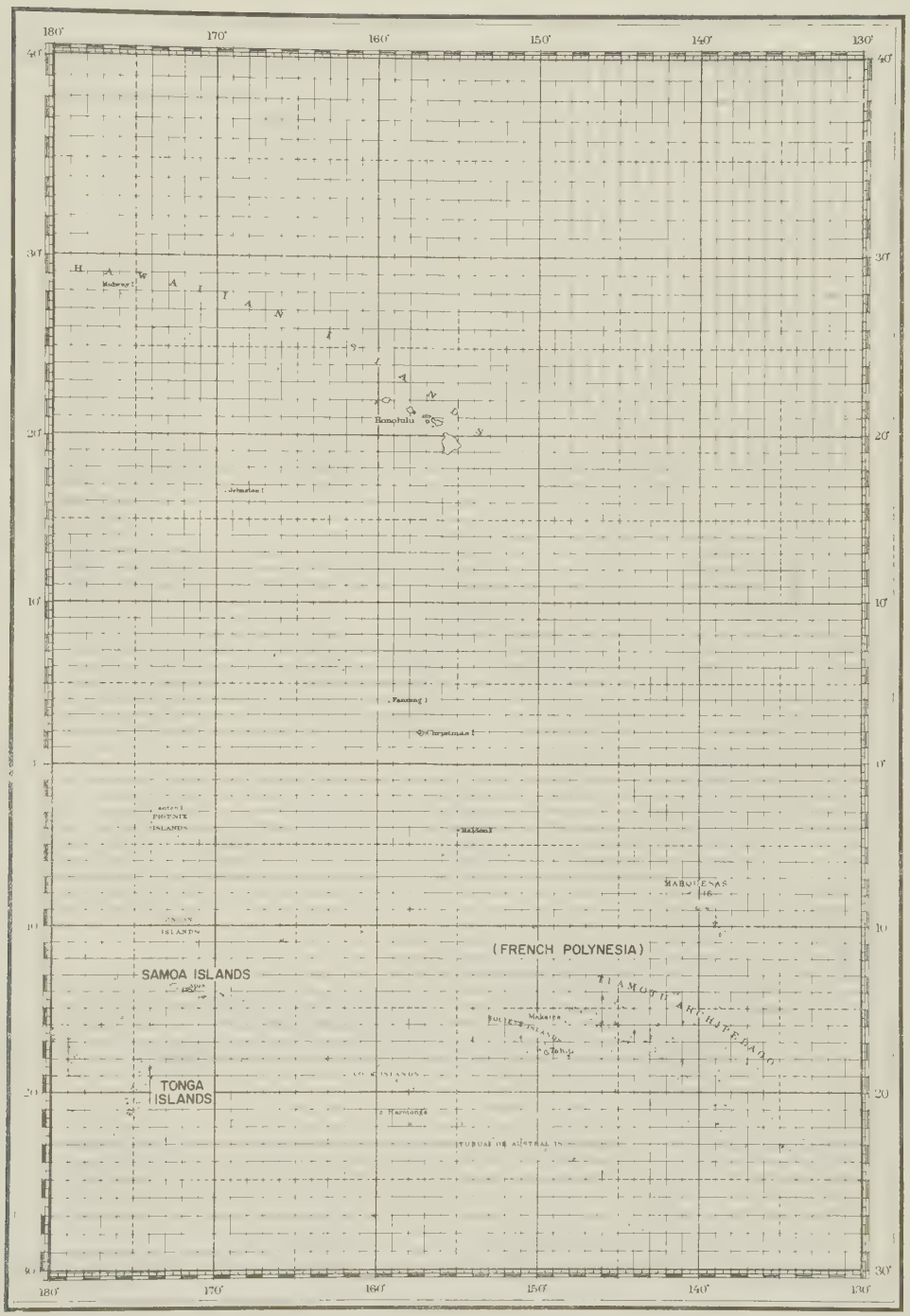


Figure 1. Island groups in the central Pacific Ocean.

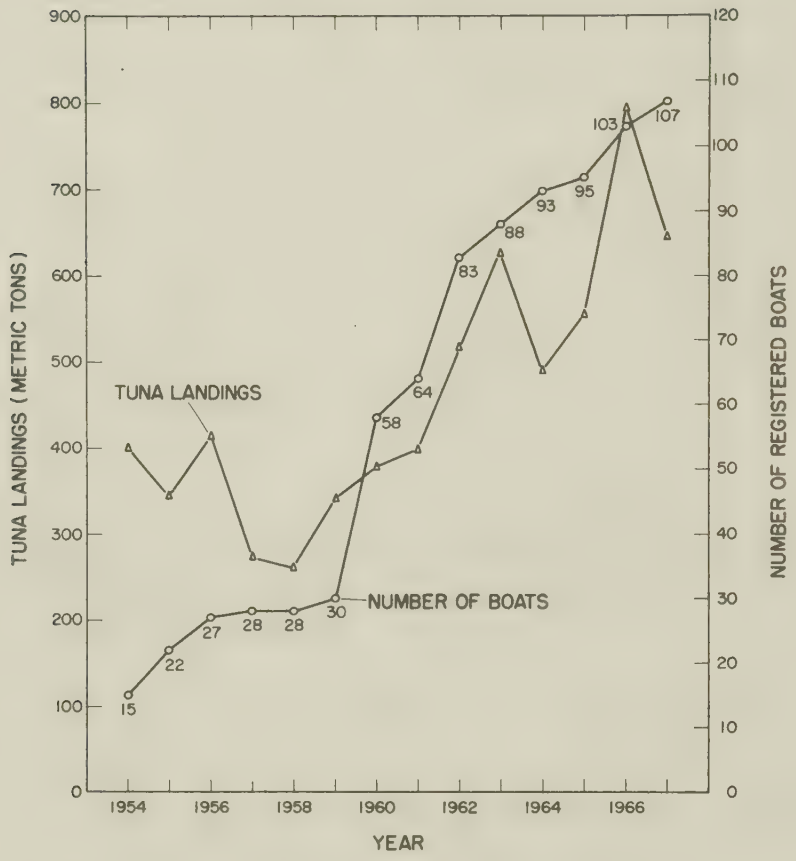


Figure 2. French Polynesia

Combined landings of skipjack and yellowfin tunas, and numbers of boats engaged in the tuna fishery (from Brun and Klawe, 1968).

Figure 3. Island groups and countries in the western Pacific Ocean.

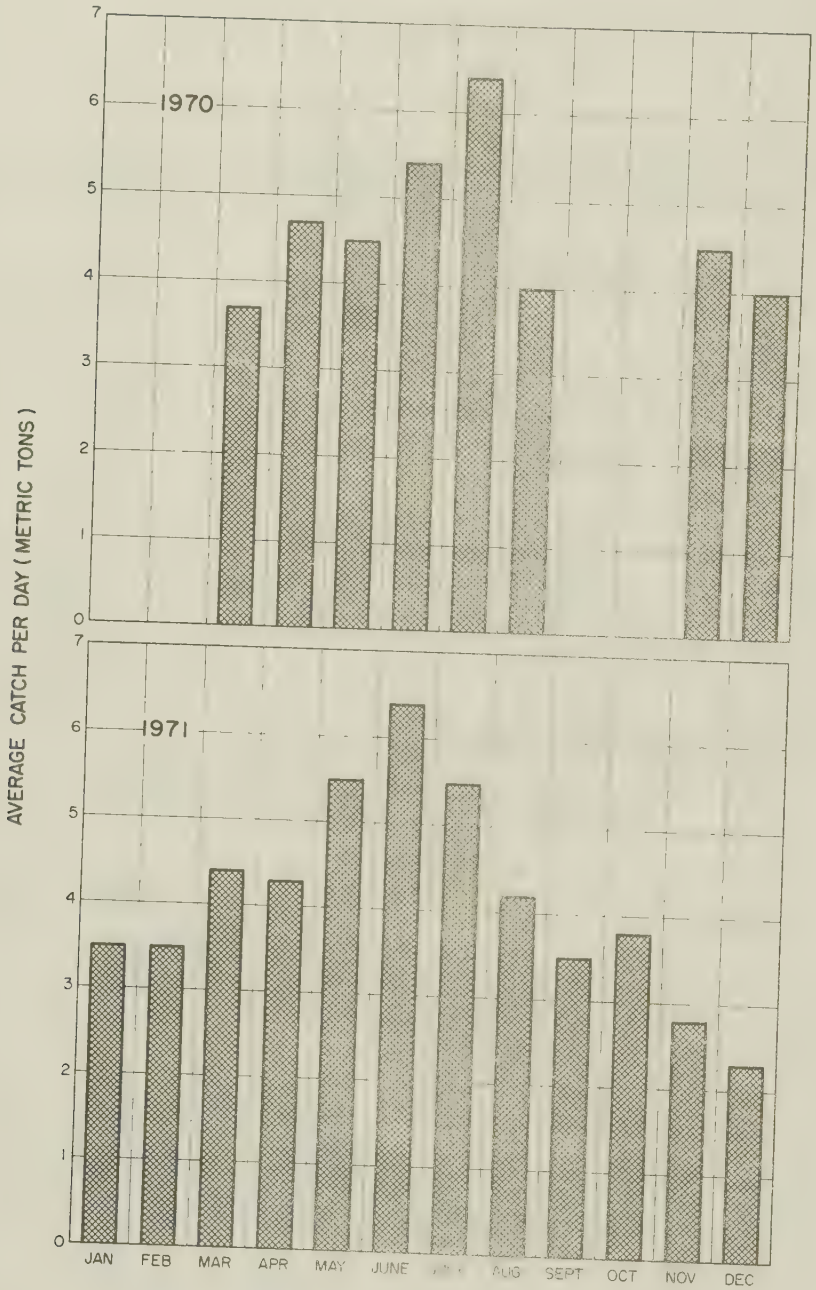
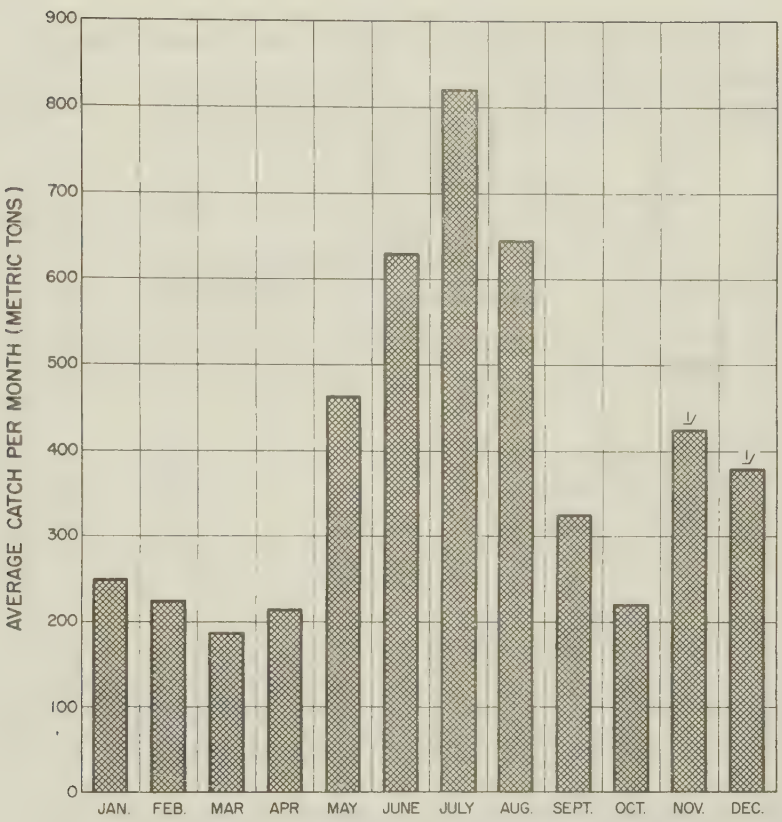


Figure 4. The average catch per day, by month, in the Papua New Guinea fishery, 1970-71.



[1]Based on data for 1966-70.

Figure 5. Average monthly catch of skipjack tuna in the Palau fishery, 1966-71.

Figure 6. Island groups within and bordering the Indian Ocean.

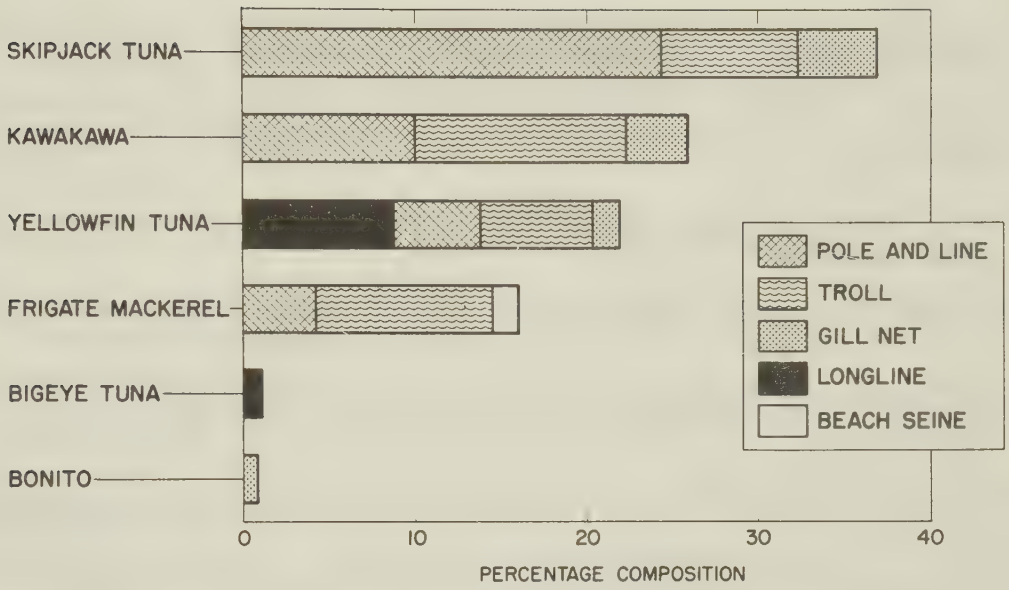


Figure 7. Sri Lanka

Percentage composition of tuna species caught from the coastal waters (from Sivasubramaniam, 1965).

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THE STOCK STRUCTURE OF SKIPJACK RESOURCES AND THE POSSIBLE IMPLICATIONS ON THE DEVELOPMENT OF SKIPJACK FISHERIES IN THE CENTRAL AND WESTERN PACIFIC

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1. INTRODUCTION

The skipjack (Katsuwonus pelamis) has in recent years been the centre of a rejuvenated hope to greatly expand the world's total production of tuna. Considerable increases in skipjack catches have occurred throughout the world but by far the most significant have been in the western Pacific Ocean. Most of the increased landings in this area have been a result of increased activities by Japanese live bait vessels in the Japanese coastal fishery, the southernwater fishery and in participation in joint venture operations in the south western equatorial regions. Although most of the increased catches can be attributed to Japanese initiative, Japan is only one of many countries interested in the development of skipjack fisheries in the western Pacific.

The first part of this document, prepared by Uchida, gives a good coverage of the areas in which expansion of skipjack fisheries has taken place or is projected to occur in the future; however, very little information has as yet been presented on the stocks of skipjack being exploited in these new fisheries or on the possible implications that the stock structure may have on existing operations and future developments. In this study an attempt has been made to collate the little published data available and to comment on several unpublished hypotheses in an attempt to gain a preliminary appraisal of some of the projections and problems associated with the extremely rapid expansion of skipjack fisheries in the western Pacific Ocean.

The expansion in the total catch of skipjack from the western Pacific Ocean between 1965 and 1972-73 (Table 1) has been largely a result of the increased fishing effort by Japan based long-range live bait and pole vessels and the establishment of several new joint-venture operations in southern areas. The catch by Japanese based vessels fishing in waters south of 20°N has increased from 53 400 tons in 1970 to 106 800 tons in 1973 and together with the expanded catches by joint-venture vessels in Papua New Guinea and the British Solomon Islands has resulted in an increase of 98 140 tons in this four-year period.

The expansion in the catches by Japanese pole and line vessels has prompted an increase in interest in skipjack fisheries by every country in the region. This accelerated interest is clearly indicated by the greater number of countries planning commencement of commercial skipjack operations or the expansion of existing fisheries (see Part I of the present document).

Several Japanese sources have indicated that the potential yield of skipjack in the Pacific could be as high as 1 000 000 tons (Suda, 1972 and see also Hester and Otsu, 1973) but there has not as yet been sufficient data accumulated to inspire confidence in any resource estimates which may have been given. Accepting the limitations imposed by this lack of data, several apparent characteristics of the fishery are considered.

2. STOCK DESCRIPTION

2.1 Blood studies

Based on analyses of the blood characteristics (especially the serum esterase systems) of skipjack, Fujino (1972) discussed the possible separation of a western Pacific subpopulation from the central and eastern Pacific subpopulation(s) (Fig. 1). The additional catch and biological data available in recent years from the areas shown in Fig. 1 as a result of the expansion in the skipjack fisheries, tends to generally support the theories of Fujino and should be considered in detail.

2.2 Size composition of the catch

The greater part of the western Pacific skipjack catch is taken by the Japanese local pole and line fishery (Table 1 area 61), the Japanese long-range southern water fishery (areas 61 and 71) and the joint-venture operations in Papua New Guinea (area 71). Size composition data is available from all these fisheries and while it is by no means ideal, it is adequate to enable the catches to be classified as being comprised of fish of greater or less

Table 1

Skipjack catches in the western Pacific Ocean as recorded by FAO

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
STATISTICAL AREA 61, PACIFIC NORTHWEST										
Japan	167 600	132 800	191 600	154 200	125 900	138 800	151 300	99 100	160 700	201 000
Korea	3 100	2 200	4 200	3 800	2 300	1 700	2 800	2 800	4 300	(4 000)
Other Asian countries	19 600	13 000	16 800	21 800	21 700	24 300	14 900	20 700	(20 000)	(20 000)
TOTAL	190 300	148 000	212 600	179 800	149 900	164 800	169 000	122 600	185 000	225 000
STATISTICAL AREA 71, PACIFIC WEST CENTRAL										
British Solomons								4 700	7 000	(7 000)
Indonesia 1/				11 716	12 907	13 413	13 642	13 350	13 317	(13 000)
Japan			35 700	34 700	40 100	40 900	53 400	79 300	75 500	106 800
New Hebrides 3/	2 900	3 400	5 700	4 800	6 700	6 800	6 800	6 800	6 800	(6 800)
Palau 2/			2 941	3 403	5 212	6 186	8 441	1 716	(5 000)	(6 000)
Papua New Guinea							2 350	16 830	11 350	26 690
Philippines				500	2 400	600	200	700	3 500	2 500
TOTAL	2 900	3 400	44 341	55 119	67 319	67 899	84 833	123 396	122 467	168 790
STATISTICAL AREA 81, PACIFIC SOUTHWEST										
Australia										(1 500)
Japan	300			200	100					
New Zealand							100	200	200	(500)
TOTAL	300			200	100		100	200	200	2 000
TOTAL 61 + 71 + 81	193 500	151 400	256 941	235 119	217 319	232 699	253 933	246 196	307 667	395 790

1/ Figures from Gulland, 1972

2/ Figures from Part I - prepared by Uchida - of the present document

3/ These figures, previously incorrectly reported as skipjack, are probably tuna longline catches including not more than a few hundred tons of skipjack

( ) Catches estimated from previous years' data for the purpose of the study

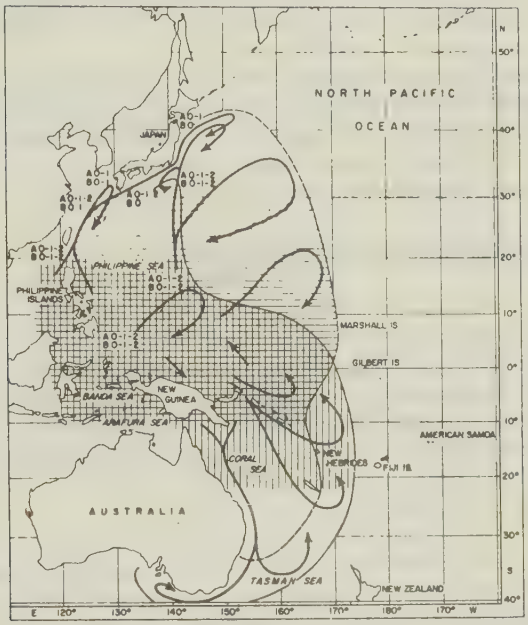

Figure 1: Proposed range and migration routes of skipjack tuna subpopulation in the western Pacific Ocean. Eastern limit of range in the northern winter (southern summer) and northern summer (southern winter) are indicated by a thin solid line and a broken line, respectively. These two lines also represent approximate western limits of ranges of the central and eastern Pacific skipjack tuna subpopulation(s) in the two seasons. Intensive spawning grounds in the northern summer and winter are shown as the areas hatched horizontally and vertically, respectively. Thick solid lines with arrows represent proposed major routes of migration of both group A and B as described in the text. Thick broken lines with arrows show possible infrequent intermingling across the Equator between northern and southern fish. Numerals with a letter A or B mean age classes of fish by group (A or B) in each location, as described in the text. (Sources: Japan, Fishing Ground Knowledge Popularizing Association, 1968; Kawasaki, 1955a, 1955b, 1964; Fujino, in press a). Such numerals are not shown for the Southern Hemisphere for lack of data. (From Fujino, 1972, Fig.4)

than 6 kg. This can be shown to be an extremely significant division for the purposes of stock description.

Skipjack catches taken in the Japanese coastal waters consist predominantly of fish in the 40–55 cm range (1.2–3.4 kg) (Suda, 1971) while the fish taken by long-range vessels in the lower latitudes tend to be larger. An analysis of the figures given for the catches by the southernwater fleet during the period July 1973–May 1974 inclusive (Tohoku Regional Fisheries Research Laboratory, 1974) indicates that approximately 2.6 percent of the estimated 136 000 tons taken (Otsu, 1974) was of fish greater than 6.0 kg. It further shows that almost all of the larger fish were taken near the eastern extremities of the fishery, which in fact lies outside the boundaries of the western population postulated by Fujino.

Average size figures (Kearney, 1973) and length frequency analyses (Department of Agriculture, Stock and Fisheries unpublished data) for the Papua New Guinea fishery reveal that fish above 6 kg are rare and account for far less than 1 percent of the total annual catch, while fish above 7 kg are almost never taken.

In contrast the established fisheries of the central Pacific rely heavily on very large season fish of at least 8 kg (Hawaii) and often much larger (Tahiti).

This data therefore clearly shows that the size composition of skipjack from the western Pacific is entirely different to that of the more eastern population(s). When the proposed low L_∞ for skipjack in the west and the lack of easterly migrations by tagged skipjack are also considered, it appears extremely unlikely that these size differences are a result of exploitation of different year classes of the same population.

2.3 Migration patterns as indicated from tagging

In the second draft of the third interim report of the Working Party on tuna and billfish tagging in the Pacific and Indian Ocean, Bayliff et al. (1974) report that up to the time of compilation of the report 22 822 skipjack had been tagged and released in Pacific waters west of 180° most of the tagging having been carried out by the Tohoku Regional Fisheries Research Laboratory (Japan), the Department of Agriculture, Stock and Fisheries (Papua New Guinea) or the Far Seas Fisheries Research Laboratory (Japan). Of these releases 952 had been recorded as recaptured.

Preliminary analyses of this tagging information have revealed considerable poleward migration of skipjack within the boundaries of latitudes 130°E and 160°E with fewer than ten recaptures outside these limits (Tohoku Laboratory unpublished data, Lewis MS, Department of Agriculture, Stock and Fisheries unpublished data). None of the skipjack tagged in the western Pacific have been recaptured further east than 173°E.

Further analyses of the migrations of recaptured fish indicate the existence of two distinguishable groups in this western Pacific population which could well be the same as the A and B groups postulated by Fujino (1972). The tagging data from Papua New Guinea, where a comparatively large number of fish have been released on a more regular basis, strongly indicate the presence of several distinguishable groups, consistent with the hypothesis that these groups are the result of separate northern and southern spawnings of the same parent population, or which may possibly be entirely separate stocks.

2.4 Growth

The most comprehensive comparative study of the growth of skipjack in the western, central and eastern Pacific is that given by Joseph and Calkins (1969). However, since the publication of this work the amount of data available for the western Pacific has been greatly increased by the tagging studies in Papua New Guinea (Kearney unpublished data presented at the Lake Arrowhead Tuna Conference, 1974) and otolith analyses carried out at the NMFS Honolulu Laboratory (Struhsaker unpublished data presented Lake Arrowhead Tuna Conference, 1974). From the Papua New Guinea tagging experiments in which in excess of 600 fish have been recaptured after periods at liberty of up to 650 days growth rates have been analyzed in detail. Recapture information on skipjack released in 1972 indicates an annual average growth of 7 cm for skipjack taken in this fishery (viz. 45–65 cm). This figure has been substantiated by preliminary evaluation of the 1973 release and recapture data which were based upon measured length at release rather than mean size of individuals within a school.

The study of Joseph and Calkins (1969) indicates that growth rates and L_∞ of skipjack in the central and eastern Pacific differ from those found in Papua New Guinea. The L_∞ of 65 cm obtained from the Papua New Guinea data is much lower than that of any of the estimations reviewed by Joseph and Calkins (1969) which averaged 87.4 cm and as expected for the lower L_∞ the K value of 0.92 is much higher than those for fish in the eastern and central Pacific (average from Joseph and Calkins 0.63).

Preliminary analysis of the NMFS Honolulu Laboratory data on the ageing of skipjack by otolith readings also indicates slower growth rates for fish from the western Pacific. The accumulated evidence therefore strongly supports the theory that skipjack in this region have a much slower growth rate and a lower L_∞ than fish in the central and eastern Pacific.

2.5 Longline catches of skipjack

Although skipjack is not a target species for existing longline fisheries, incidental catches made by longline vessels operating in the Pacific are of interest when considering the distribution and migrations of skipjack stocks.

The gear and baits used in the oceanic longline fisheries are designed for larger tuna species and as such are selective for larger skipjack. There is therefore a tendency for longline caught skipjack to be, on the average, larger than the average for the population represented by catches made with other types of gear.

It has been demonstrated that the skipjack c.p.u.e. by longline is higher for the eastern Pacific than for the western sector (Kasahara, 1968; Miyake, 1968) and there is also a tendency for the skipjack taken in the equatorial western Pacific to be smaller than those from other regions (Miyake, 1968). These two factors are consistent with the postulated low L_∞ for skipjack in the western sector and also strongly support the hypothesis that no large unfished stocks of sizeable fish exist in that region, particularly when the intensity of longline fishing in the western Pacific is also considered.

2.6 Larval distribution and spawning

Several studies on the distribution of larval and juvenile skipjack have been reported (Matsumoto, 1966; Ueyanagi, 1969; Matsumoto, 1974 unpublished data presented at the Lake Arrowhead Tuna Conference), and Suda (1972) has used figures on larval concentrations as the basis for preliminary stock estimates. There is general agreement that skipjack larvae are widely distributed throughout the tropical Pacific with a definite increase in concentration with progression westwards. The comparative lack of skipjack larvae in the eastern Pacific, together with the data accumulated from a small number of recaptured tagged skipjack, has indicated that some, if not all of the population exploited by the U.S. purse seine fishery migrates into the central Pacific to spawn. Also, although the data available are by no means conclusive, it would appear that the size at first maturity of skipjack of approximately 45 cm is similar for fish from both sides of the Pacific (Kearney *et al.*, 1972; Lewis *et al.*, 1974; Brock 1954; Orange 1961) but as has already been discussed, the growth rates from then on are entirely different. It could therefore be possible that although the skipjack migrating from the eastern to the central Pacific reach maturity they do not spawn at anywhere near the frequency of the western population(s) and the energy thus conserved is used for growth, possibly resulting in the variant L_∞ for the two groups.

2.7 Physiological limitations imposed on the L_∞ of skipjack

At the 25th Lake Arrowhead Tuna Conference, Drs. Neill and Barkley considered possible restrictions on the maximum size of skipjack imposed by the species' extremely high metabolic rate and the water temperature and oxygen content of its environment. The oxygen and heat dissipation of the species suggests that the largest individuals cannot survive for long periods in very warm low oxygen content water, as encountered in the surface layers of the equatorial Pacific. It was pointed out that large skipjack were probably required to make frequent excursions into cooler, higher oxygen content water.

It is the author's opinion that these findings are consistent with the available data on the distribution of large skipjack and render the western equatorial Pacific, with its deep thermocline, an unfavourable environment for very large skipjack. It may be that the energy, oxygen and heat dissipation requirements of the species, together with variable energy expenditure on growth and spawning, are in some way responsible for the spatial separation of at least two major skipjack populations in the Pacific Ocean.

3. CONSEQUENCES ON FISHERY DEVELOPMENT PERSPECTIVES

The Japanese coastal water skipjack fishery has for many years been the largest and most stable skipjack fishery in the western Pacific and while it was considered that this fishery was approaching its maximum size, its future was commonly regarded as assured (Kasahara, 1968 and 1971; Suda, 1972). The progression southward by the long-range fleet has substantially increased the total landings of skipjack from the western Pacific, particularly since 1971 (Table 1). These increased landings may result from:

(i) increasing the area of exploitation of the stocks utilized in the Japanese coastal fishery, or

(ii) exploiting additional stocks of this species previously not subjected to any great degree of fishing pressure.

The information discussed in this report suggests that the latter is the more likely. It is considered that the more easterly expansion in the skipjack fishing effort in recent years has resulted in an increase in the landings in Japan of skipjack from the central and eastern subpopulations(s). It is also possible that the increased catches from southern waters consist largely of fish from a separate southern summer spawning (group B of Fujino, 1972) which had previously been underutilized. If the two groups (A and B) postulated by Fujino (1972) are real then it would appear that the skipjack north of 20°N are almost entirely group A, fish from 20°N to 10°S are of both groups but south of 10°S group B predominates. Recent tagging studies generally support this hypothesis for although fish tagged in the central regions have migrated to both the northern and southern extremes of the fishery, fish tagged in the northern or southern limits have not as yet been shown to undergo reverse migrations (Tohoku Regional Fisheries Research Laboratory unpublished data and Department of Agriculture, Stock and Fisheries unpublished data).

The possible inclusion of central and eastern subpopulation(s) fish in the catches taken in the northern and eastern extremities of the existing western Pacific skipjack fishery has been discussed here and by Fujino (1972). However, even less is known about the skipjack taken in the southern latitudes of the western Pacific. The size composition of the catches taken from the New Hebrides and New Caledonia waters would tend to suggest that both areas are frequented, at least on a seasonal basis, by some fish of the central and eastern subpopulation(s), while very little is known about the skipjack taken off Australia and New Zealand. Fujino (1972) studied samples from New Zealand and assigned these fish to the central rather than western population and the occurrence of an area of ocean off the east Australian coast (bordered by 20°S–32°S and 150°E–160°E) which is apparently almost completely devoid of skipjack even though its obvious physical attributes appear favourable for the species, would support the possibility of a division of the stocks centred on this region.

If the above postulated division of the stocks are in fact real then the expanded skipjack fishing in the western Pacific must be considered along the following lines:

(a) The fish which accounted for the majority of the Japanese skipjack landings prior to 1971 (i.e. group A) have since 1968 been subjected to increased fishing effort without any obvious deleterious effects. Several authors have, however, postulated that this fishery is rapidly approaching optimum fishing intensity (Kasahara, 1971; Suda, 1972). One possible adverse influence of the spatial expansion of the fishery is a result of the complementary increase in the temporal exploitation of each year class. The southward expansion of the fishery has resulted in an almost year-round season which has greatly increased the time of exposure of individuals to the fishery. This could be anticipated to result in an increase in the yield per recruit but may not result in an increase in total yield if recruitment is appreciably influenced by the elevated fishing effort. The results of tagging experiments for skipjack in the western Pacific would indicate that individuals are exposed to the fishery for approximately three years.

This may tend to render them more susceptible to overexploitation than fish in the eastern Pacific where the exposure time is of the order of 6 months (Rothschild, 1966); however much more information about natural and total mortalities, fecundity, percentage larval survival and recruitment, etc., are required before any generalizations can be made.

(b) Many of the fish taken in the southern part of the expanded fishery (south of 20°N, i.e. group B) are from stocks previously not subjected to any substantial exploitation. If this is in fact the case then separate management procedures could be required for the separate fisheries but the possibility of a sizeable fishery in the southern equatorial regions of the western Pacific, relatively independent of fishing pressure in the more northerly Japanese fishery, is enhanced.

(c) Many of the skipjack taken on the eastern extremities of the distribution of the western population and the fish from southern Australian and New Zealand waters may well be from the central and eastern population(s). If, as is anticipated, this population(s) is underutilized, then further expansion into areas not at present being heavily fished, would appear likely to result in still further increases in the total skipjack landings from the western and central Pacific.

4. THE IMPORTANCE OF THE BAITFISH RESOURCES

Although most of the skipjack catches in the eastern Pacific have in recent years been taken by purse-seine vessels, live bait pole vessels continue to dominate the fishery in the western regions. The clarity of the water and the lack of a suitable thermocline are the two factors normally considered most responsible for the comparative failure of purse-seining in the western Pacific.

Since 1966 the efforts to develop techniques suitable for skipjack and tuna purse-seining in the coastal waters of Japan and in the southern grounds have been intensified and it is believed that the catches made by Japanese purse-seine vessels in these areas in 1974 were indeed most encouraging. In addition, the recent inflated construction of super-seiners in the United States of America has resulted in the total capacity of the U.S. fleet exceeding the quota for yellowfin stipulated by the I-ATTC. This is predicted to result in increased fishing effort for skipjack certainly in the eastern Pacific and probably in more western areas. It is probable that the increasing interest in skipjack in the western Pacific will result in an increase in the landings by purse-seine vessels in this area; however it appears that live bait vessels will continue to dominate the catches in the immediate future and will play a major role in the fishery for many years.

The distribution of Engraulis anchovies[1/] in the higher latitudes greatly facilitated the development of the skipjack fishery in Japan and endows Australia and New Zealand with latent potential to expand their participation if sizeable stocks of skipjack can be found in the southern western Pacific. Expansion of the Japanese southernwater fishery was made possible by improving the techniques of handling Engraulis japonica (Suda, 1972) but the remainder of the increased fishing effort in equatorial waters has been a result of wider utilization of Stolephorus anchovies. While such anchovies have been found to occur in most island regions of the equatorial Pacific, stocks sufficient to support even moderate skipjack fleets appear to be limited to the vicinity of the larger land masses. Papua New Guinea and the British Solomon Islands have developed skipjack fisheries which are still expanding while the limited resources of Stolephorus purpureus in Hawaii have limited the size of the skipjack fishery there (Wetherall, 1974 unpublished data).

1/ Engraulis japonica in Japan and Engraulis australis in Australasia.

Most of the smaller island countries and territories of the western and central Pacific would appear to be surrounded by at least fair skipjack stocks but the scarcity of baitfish is restricting fisheries in many of them. The use of cultured baitfish for the establishment of small scale live bait fisheries would appear the best prospect for many of them, e.g. American Samoa.

The recent encouraging results in improving the handling and hence the efficiency of utilization of Stolephorus anchovies in Papua New Guinea (Kearney, 1974; Smith, 1974) enhances expansion of skipjack fisheries in those countries which have sizeable baitfish resources and indicates future competition to the current Japanese domination of long-range pole fishing operations. The possible entry of Korea, the Philippines and other Asian fishing nations, which have sizeable stocks of Engraulis anchovies, into the international skipjack fishing grounds may well play an important role in the future management of the fisheries.

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